Vol. V. — No. 10. October 1923.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[69. (01]

Tentative specifications for concrete and reinforced concrete.

The August 1921 (vol. XLVII, No. 6) number of the *Proceedings of the American Society of Civil Engineers* contains a Progress Report of the Joint Committee set up to deal with specifications for concrete and reinforced concrete.

The Committee was a strong one, and consisted of representatives of five interested Societies or Associations and issued the Report for criticism.

We publish an extract of the Preface and the main body of the Report, which it is felt is of very great interest to Railway Engineers.

PREFACE.

The Joint Committee on Standard specifications for concrete and reinforced concrete consists of five representatives from each of the following :

American Society of Civil Engineers;
American Society for Testing Materials;
American Railway Engineering Association;
American Concrete Institute;
Portland Cement Association.

The Joint Committee, in submitting these Tentative specifications for concrete and reinforced concrete in accordance with the foregoing requirement, wishes it clearly understood that it reserves the right to make such changes as may be found desirable, after a further study of the available data. While not prepared to submit a final report at this time, the Joint Committee is of the opinion that the specifications are in such shape as to make it desirable to issue them tentatively for the purpose of facilitating the final submission of Standard specifications for concrete and reinforced concrete.

The Joint Committee further calls attention to the fact that it has undertaken to prepare specifications covering the fundamentals to be observed in the general use of concrete and reinforced concrete; no attempt has been made to cover the details involved in the use of these materials in special structures. While the sections relating to design deal primarily with building construction, nevertheless the principles involved are in general applicable to structures of other types. It is expected that in using these specifications the necessary supplemental requirements will be added covering details.

CHAPTER I.

General instructions.

1\. — These specifications are not complete; they cover the general conditions affecting the use of concrete and reinforced concrete. To complete them it will be necessary for the engineer to

a) Provide the detail specifications covering the work in particular in which the concrete and reinforced concrete are to be used;

b) Insert in section 4 the strengths required for the several classes of concrete specified, based either upon preliminary tests or upon the values given in table 4 (referred to at the end of this article);

c) Insert in section 14 the sizes of aggregates required;

d) Strike out one of the titles of the specifications in section 20;

e) Strike out one of the titles of the specifications in section 24;

f) Strike out one of the words « volume » or « weight » in section 27;

g) Strike out two of the three sections 28 and fill in the necessary blanks for the proportions;

h) Insert in section 29 the slumps required;

i) Strike out the method or methods inapplicable to the work in section 50;

j) Strike out one of the two sections 97.

CHAPTER II.

Definitions.

2\. — The following definitions give the meaning of certain terms as used in these specifications :

Acid proofing. — Treatment of a concrete surface to resist the action of acid solutions.

Aggregate. — Inert material which is mixed with Portland cement and water to produce concrete; in general, aggregate consists of sand, pebbles, gravel, crushed stone or gravel, or similar materials. (See *Fine aggregate; Coarse aggregate.*)

Approved. — Meeting the approval of, or specifically authorized by, the Engineer.

Buttressed retaining wall. — A reinforced concrete wall having a vertical stem and a horizontal base, with brackets on the side opposite the pressure face uniting the vertical section with the toe of the base.

Cantilever retaining wall. — A reinforced concrete wall having a vertical stem and a horizontal base, each of which resists by cantilever action the pressure to which it is subjected.

Cellular retaining wall. — A reinforced concrete wall with a horizontal base, longitudinal vertical sections, and a series of transverse walls, dividing the space between the longitudinal walls into cells which are filled with earth, or other suitable material. If the top of the cells is covered by a floor-slab, the front longitudinal wall and the filling may be omitted.

Coarse aggregate. — Aggregate retained on a No. 4 sieve and of a maximum size generally not larger than 3 inches. (See *Aggregate: Fine aggregate.*)

Column. — A vertical compression member whose length exceeds three times its least horizontal dimension.

Column capital. — An enlargement of the upper end of a reinforced concrete column built monolithic with the column and flat slab to increase the moment of inertia of the column and the shearing resistance of the slab at sections where high bending moment or high shear may occur.

Column strip. — A portion of a panel

of a flat slab which has a uniform width equal to one-fourth of the panel length on a line perpendicular to the direction of the strip, and whose outer edge lies on the edge of the panel. (See *Middle strip.*)

Concrete. — A mixture of Portland cement, fine aggregate, coarse aggregate, and water. (See *Mortar.*)

Consistency. — A general term used to designate the relative plasticity of freshly mixed mortar and concrete.

Counterforted retaining wall. — A reinforced concrete wall having a vertical stem and a horizontal base with brackets on the pressure face uniting the vertical section with the heel of the base.

Crusher-run stone. — Unscreened crushed stone. (See *Stone screenings.*)

Cyclopean concrete. — Concrete in which stones larger than one-man size are individually embedded.

Dead load. — The weight of the structure plus fixed loads and forces.

Deformed bar. — Reinforcement bar with shoulders, lugs, or projections formed integrally from the body of the bar during rolling.

Diagonal direction. — A direction parallel or approximately parallel to the diagonal of the panel.

Dropped panel. — The structural portion of a flat slab which is thickened throughout an area surrounding the column capital.

Effective area of concrete. — The area of a section of the concrete which lies between the tension reinforcement and the compression surface of the beam or slab.

Effective area of reinforcement. — The area obtained by multiplying the right cross-sectional area of the metal reinforcement by the cosine of the angle between the direction of the reinforcement bars or wires, and the direction for which the effectiveness of the reinforcement is to be determined.

Engineer. — The engineer in responsible charge of design and construction.

Fine aggregate. — Aggregate passing through a No. 4 sieve. (See *Aggregate; Coarse aggregate.*)

Flat slab. — A flat concrete floor or roof plate having reinforcement bars extending in two or more directions and having no beams or girders to carry the load to the supporting columns.

Footing. — A structural unit used to distribute wall or column loads to the supporting material, either directly or through piles.

Gravel. — Loose material containing particles larger than sand, resulting from natural crushing and erosion of rocks. (See *Sand.*)

Laitance. — The extremely fine particles which separate from freshly deposited mortar or concrete and collect on the top surface.

Live load. — Loads and forces which are variable.

Membrane water-proofing. — A coating reinforced by fabric, felt, or similar toughening material applied to structures to prevent contact of moisture.

Middle strip. — The portion of a panel of a flat slab which extends in a direction parallel to a side of the panel, whose width is one-half the panel length on a line at right angles to the direction of the strip and whose center line lies on the center line of the panel. (See *Column strip.*)

Mortar. — A mixture of Portland cement, fine aggregate, and water. (See *Concrete.*)

Negative reinforcement. — Reinforcement so placed as to take stress due to negative bending moment.

Oil-proofing. — Treatment of a concrete surface to resist the action of mineral, animal, or vegetable oils.

One-man stone. — Stone larger than coarse aggregate and not exceeding 100 lb. in weight. (See *Rubble concrete.*)

Panel length. — The distance between centers of two columns of a panel, in either rectangular direction.

Pedestal footing. — A member supporting a column, in which the projection from the face of the column on all sides is less than one-half the depth.

Pedestal or pier. — A vertical compression member whose length does not exceed three times its least horizontal dimension.

Plain concrete. — Concrete without metal reinforcement.

Portland cement. — The product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination excepting water and calcined or uncalcined gypsum.

Positive reinforcement. — Reinforcement so placed as to take stress due to positive bending moment.

Principal design section. — The vertical sections in a flat slab on which the moments in the rectangular directions are critical. (See section 146.)

Ratio of reinforcement. — The ratio of the effective area of the reinforcement cut by a section of a beam or slab to the effective area of the concrete cut by that section.

Rectangular direction. — A direction parallel to a side of the panel.

Reinforced concrete. — Concrete in which metal is embedded in such a manner that the two materials act together in resisting stress.

Rubble aggregate. — Stone or gravel larger than coarse aggregate and not larger than one-man stone. (See *One-man stone.*)

Rubble concrete. — Concrete in which pieces of rubble aggregate are individually embedded. (See *Rubble aggregate.*)

Sand. — Loose material consisting of small grains (commonly quartz) resulting from the natural disintegration of rocks. (See *Gravel.*)

Screen. — A metal plate with closely spaced circular perforations. (See *Sieve.*)

Sieve. — Woven wire cloth with square openings. (See *Screen.*)

Slump. — The shortening of a standard test mass of concrete used as a measure of workability.

Standard sand. — Natural sand mined at Ottawa, Ill., screened to pass a No. 20 sieve and retained on a No. 30 sieve, used as the fine aggregate in standard strength tests of Portland cement.

Stone screenings. — Unscreened crushed stone passing through a No. 4 sieve. (See *Crusher-run stone.*)

Tremie. — A water-tight pipe of suitable dimensions, generally used in a vertical position, for depositing concrete under water.

Wall-beam. — A reinforced concrete beam which extends from column to column along the outer edge of a wall panel.

CHAPTER III.

Quality of concrete.

3. — *Quality.* — The quality of concrete shall be expressed in terms of workability as determined by the slump test, and of the compressive strength at 28 days as determined by concrete tests

of the materials to be used, as specified in section 28. The proportions required to produce concrete having the strength specified in section 4 shall be determined in advance of the mixing of the concrete.

4. — *Strength.* — The concrete shall develop under the conditions specified in section 3, for the various parts of the work, the following strengths (1):

.... lb. per square inch.
.... lb. per square inch.
.... lb. per square inch.
.... lb. per square inch.

5. — *Tests of field specimens.* — Field concrete test specimens shall be made, stored, and tested in accordance with « Standard methods of making and storing specimens of concrete in the field » (serial designation : C31—21) of the American Society for Testing Materials.

CHAPTER IV.

Materials.

A. — Portland cement.

6. — Portland cement shall conform to the « Standard specifications and tests for Portland cement » (2) (serial designation : C9—21) of the American Society for Testing Materials, and subsequent revisions thereof.

B. — Fine aggregate.

7. — *General requirements.* — Fine aggregate shall consist of sand, stone screenings, or other inert materials with similar characteristics, or a combination thereof, having clean, hard, strong, durable, uncoated grains and free from injurious amounts of dust, lumps, soft or flaky particles, shale, alkali, organic matter, loam, or other deleterious substances.

8. — *Grading.* — Fine aggregate shall range in size from fine to coarse, preferably within the following limits :

Passing through No. 4 sieve	not less than 95 %
Passing through No. 50 sieve	not more than 30 %
Weight removed by decantation	not more than 3 %

9. — *Sieve analysis.* — The sieves and method of making sieve analysis shall conform to the « Tentative method of test for sieve analysis of aggregates for concrete » (serial designation : C41—21T) of the American Society for Testing Materials.

10. — *Decantation test.* — The decantation test shall be made in accordance with the « Standard method of test for quantity of clay and silt in sand for highway construction » (serial designation : D74—21) of the American Society for Testing Materials.

11. — *Mortar strength test.* — Fine aggregate shall preferably be of such a quality that mortar briquettes, cylinders, or prisms, consisting of one part by weight of Portland cement and three parts by weight of fine aggregate (1), mixed and tested in accordance with the methods described in the « Standard specifications and tests for Portland cement »,

(1) The engineer should insert the strengths for the several classes of concrete specified, based either upon preliminary tests or upon the values given in table 4, referred to at the end of this article.

(2) These specifications are also a standard of the following organizations : American Engineering Standards Committee, United States Government, American Railway Engineering Association, American Concrete Institute, and the Portland Cement Association.

(1) In testing aggregate, care should be exercised to avoid the removal of any coating on the grains which may affect the strength. Natural sand should not be dried before being made into mortar, but should contain natural moisture. The quantity of water contained may be determined on a separate sample and the weight of the sand used in the test corrected for the moisture content.

will show a tensile or compressive strength at ages of 7 and 28 days not less than that of 1:3 standard Ottawa sand mortar of the same plasticity made with the same cement. However, fine aggregate which fails to meet this requirement may be used, provided the proportions of cement, fine aggregate, coarse aggregate, and water are such as to produce concrete of the strength specified (1). Concrete tests shall be made in accordance with the « Tentative methods for making compression tests of concrete » (serial designation : C39—21T) of the American Society for Testing Materials.

12. — *Organic impurities in sand.* — Natural sand which shows a color darker than the standard color when tested in accordance with the « Tentative method of test for organic impurities in sand for concrete » (serial designation : C40—21T) of the American Society for Testing materials, shall not be used, unless the concrete made with the materials and in the proportions to be used on the work is shown by tests to be of the required strength.

C. — Coarse aggregate.

13. — *General requirements.* — Coarse aggregate shall consist of crushed stone, gravel, or other approved inert materials with similar characteristics, or combinations thereof, having clean, hard, strong, durable, uncoated particles free from injurious amounts of soft, friable, thin, elongated or laminated pieces, alkali, organic, or other deleterious matter.

14. — *Grading.* — Coarse aggregate shall range in size from fine to coarse within the following limits (2) :

Passing (3) inches sieve (maximum size)	not more than 95 %
Passing (3) inches sieve (intermediate size)	(3) to (3) %
Passing No. 4 sieve	not more than 15 %
Passing No. 8 sieve.	not more than 5 %

15. — *Sieve sizes.* — The test for size and grading of aggregate shall be made in accordance with the « Tentative method of test for sieve analysis of aggregate for concrete » (serial designation : C41—21T) of the American Society for Testing Materials.

(1) Table 4 (referred to at the end of this article) furnishes a guide in determining the proportions of materials required to produce a concrete of a given strength, using aggregates of various sizes and concrete of different consistencies.

(2) Where several suitable aggregates are available, a thorough investigation of the relative economy of each for producing concrete of the desired strength is advisable, especially for work of considerable magnitude.

(3) The engineer should insert in these blanks the sizes of aggregates required. The size and grading to be used will be governed by local conditions. The limitation on size and grading is intended to secure uniformity of aggregate. The following table indicates desirable gradings for coarse aggregate for certain maximum sizes :

Maximum size of aggregate, in inches.	Percentage by weight passing through standard sieves with square openings.					Percentage passing, not more than	
	3 inches.	2 inches.	$1\frac{1}{2}$ inches	1 inch.	$\frac{3}{4}$ inch.	No. 4 sieve.	No. 8 sieve.
3	100	...	40-75	...	...	15	5
2	...	100	...	40-75	...	15	5
$1\frac{1}{2}$	..	...	100	...	40-75	15	5
1	...	...	...	100	...	15	5
$\frac{3}{4}$	...	...	...	...	100	15	5

D. — **Rubble and cyclopean aggregate.**

16. — *Rubble aggregate.* — Rubble aggregate shall consist of clean, hard, durable stone larger than coarse aggregate and not larger than one-man stone.

17. — *Cyclopean aggregate.* — Clyclopean aggregate shall consist of clean, hard, durable stone, free from fissures and planes of cleavage and larger than one-man stone.

E. — **Storage of aggregate.**

18. — *Aggregate storage.* — Aggregate shall be so stored on platforms or otherwise as to avoid the inclusion of foreign materials. Before using, frost, ice, and lumps of frozen materials shall be removed.

F. — **Water.**

19. — *General requirements.* — Water for concrete shall be clean and free from oil, acid, alkali, organic matter, or other deleterious substance.

G. — **Metal reinforcement.**

20. — *Quality.* — Metal reinforcement shall be of a quality and character meeting the requirements of the « Standard specifications (1) for Billet-steel concrete reinforcement bars » (serial designation: A15—14), of the American Society for Testing Materials, « Standard specifications (1) for rail-steel concrete reinforcement bars » (serial designation: A16—14), of the American Society for Testing Materials, except that the provision for machining deformed bars before testing shall be eliminated.

(1) The engineer should strike out one of these titles. The Committee recommends as preferred material for reinforcement that meeting the requirements of the « Standard specifications for billet-steel concrete reinforcement bars » (serial designation : A15—14), of intermediate grade (except as noted under section 20), made by the open-hearth process.

21. — *Wire.* — Wire for concrete reinforcement shall conform to the requirements of the « Tentative specifications for cold-drawn steel wire for concrete reinforcement » (serial designation : A82—21T), of the American Society for Testing Materials.

22. — *Standard sizes of bars.* — Reinforcement bars shall conform to the areas and equivalent sizes shown in table 1.

The areas of deformed bars shall be determined by the minimum cross-section thereof.

Table 1. — **Sizes and areas of reinforcement bars.**

Size of bar, in inches.	Area, in square inches.	
	Round.	Square.
$^3/_8$	0.110	...
$^1/_2$	0.196	0.250
$^5/_8$	0.307	...
$^3/_4$	0.442	...
$^7/_8$	0.601	...
1.	0.785	1.000
1 $^1/_8$	...	1.266
1 $^1/_4$	...	1.563

23. — *Deformed bars.* — An approved deformed bar shall be one that will develop a bond strength at least 25 % greater than that of a plain round bar of equivalent cross-sectional area (2).

24. — *Structural shapes.* — Structural steel shapes used for reinforcement shall conform to the requirements of « Standard specifications (3) for structural steel for bridges » (serial designation: A7—21), of the American Society for Testing Materials, « Standard specifications (3) for

(2) The Committee has under consideration a specification for deformed bars, but is not prepared at this time to make more definite recommendations.

(3) The engineer should strike out one of the titles.

structural steel for buildings » (serial designation : A9—21), of the American Society for Testing Materials.

25. — *Cast iron.* — The quality of cast iron used in composite columns shall conform to the requirements of the « Standard specifications for cast-iron pipe and special castings » (serial designation : A44—04), of the American Society for Testing Materials.

CHAPTER V.

Proportioning and mixing concrete

A. — Proportioning.

26. — *Unit of measure.* — The unit of measure shall be the cubic foot. Ninety-four (94) lb. (one bag or 1/4 bbl.) of Portland cement shall be considered as one cubic foot.

27. — *Method of measuring.* — Each of the constituent materials shall be measured separately by volume [1] weight [1]. The method of measurement shall be such as to secure the specified proportions in each batch. If volume measurement is used, the fine aggregate and the coarse aggregate shall be measured loose as thrown into the measuring device. The water shall be measured by an automatic device that will insure the same quantity in successive batches.

28 [2]. — *Proportions.* — The proportions of cement, water, and aggregate shall be such as to produce concrete of the strength and quality specified in sections 3 and 4. The proportions shall be 1 part of Portland cement ... [1] parts of fine aggregate, and ... [1] parts of coarse aggregate as determined by the engineer from concrete tests of the materials to be used. The tests shall be made in accordance with the « Tentative methods of making compression tests of concrete » (serial designation : C39—21T) of the American Society for Testing Materials. The quantity of water used shall be such as to produce concrete of the consistency required by the particular class of work, and shall be as specified in section 29. In case the grading of the supply of available aggregate varies from that upon which the proportions were based, such aggregate may be used, provided the new proportions, as determined by the engineer, are such as to produce concrete of the required strength and quality.

28 [2]. — *Proportions.* — The contractor shall use materials so proportioned and mixed as to produce concrete of the required workability and strength [3]. Frequent compression tests of the concrete used in the work will be made by the engineer, and in case of failure to meet the specified strength, the contractor shall make such changes in the materials, proportions, or mixing, as may be necessary to secure concrete of the required strength. Concrete tests shall be made in accordance with the « Standard methods of making and storing specimens of concrete in the field » (serial designation : C31—21), of the American Society for Testing Materials, and the « Tentative methods of making compression tests of concrete ».

---

(1) The engineer should strike out one of these terms.

(2) The engineer should indicate his choice of the method of proportioning to be used by striking out two of the sections numbered 28.

(1) The engineer should fill in these blanks.

(2) The engineer should indicate his choice of the method of proportioning to be used by striking out two of the sections numbered 28.

(3) The use of this method should be accompanied by a clause in the contract which indicates the procedure to be followed in case tests show that concrete of the specified strength has not been obtained.

28 (1). — *Proportions.* — The proportions shall be 1 part of Portland cement ... (2) parts of fine aggregate and ... (2) parts of coarse aggregate. The proportions of materials shall be selected from table 4. In case the grading of the supply of available aggregate varies from that upon which the proportions were based, such aggregate may be used, provided the new proportions, as determined by the engineer, are such as to produce concrete of the required strength and quality.

B. — Consistency.

29. — The engineer shall determine and specify the consistency of the concrete for various portions of the work based on tests of the materials to be used. The consistency of the concrete shall be measured by the slump test in the manner described in the « Tentative specifications for workability of concrete for concrete pavements » (serial designation : D62—20T), of the American Society for Testing Materials. The slump for different types of concrete shall not be greater than as indicated in table 2.

The consistency shall be checked from time to time during the progress of the work.

C. — Mixing.

30. — *Machine-mixing.* — Mixing, unless otherwise authorized by the engineer, shall be done in a batch mixer of approved type, will insure a uniform distribution of the materials throughout the mass, so that the mixture is uniform in color and homogeneous. The mixer shall be equipped with suitable charging hopper, water storage, and a water-measuring device controlled from a case which can be kept locked and so constructed that the water can be discharged only while the mixer is being charged. It shall also be equipped with an attachment for automatically locking the discharge lever until the batch has been mixed the required time after all materials are in the mixer. The entire contents of the drum shall be discharged before recharging. The mixer shall be cleaned at frequent intervals while in use.

(1) The engineer should indicate his choice of the method of proportioning to be used by striking out two of the sections numbered 28.

(2) The engineer should fill in these blanks.

TABLE 2. — **Workability of concrete.**

Type of concrete.	Maximum slump, in inches
1° Mass concrete	(1)
2° Reinforced concrete :	
a) Thin vertical sections and columns	(1)
b) Heavy sections	(1)
c) Thin confined horizontal sections	(1)
3° Roads and pavements :	
a) Hand-finished	(1)
b) Machine finished	(1)
4° Mortar for floor finish . . .	(1)

(1) The engineer should insert the slumps required, based on tests called for in this section. The slump test requirement is intended to insure concrete mixed with the minimum quantity of water required to produce a plastic mixture. The following table indicates the maximum slump desirable for the various types of concrete, based on average aggregates and proportions :

Type of concrete.	Maximum slump, in inches.
1° Mass concrete	2
2° Reinforced concrete :	
a) Thin vertical sections and columns.	6
b) Heavy sections.	2
c) Thin confined horizontal sections.	8
3° Roads and pavements :	
a) Hand-finished	4
b) Machine-finished	1
4° Mortar for floor finish.	2

31. — *Time of mixing.* — The mixing of each batch shall continue not less than 1 1/2 minutes after all the materials are in the mixer, during which time the mixer shall rotate at a peripheral speed of about 200 feet per minute. The volume of the mixed material per batch shall not exceed the manufacturer's rated capacity of the mixer.

32. — *Hand-mixing.* — When hand-mixing is authorized by the engineer it shall be done on a water-tight platform. The materials shall be turned at least six times after the water is added and until the batch is homogeneous in appearance and color.

33. — *Retempering.* — The retempering of concrete or mortar which has partly hardened, that is, remixing with or without additional cement, aggregate, or water, shall not be permitted.

CHAPTER VI.

Depositing concrete.

A. — Depositing in air.

34. — *General.* — Before beginning a run of concrete, hardened concrete and foreign materials shall be removed from the inner surfaces of mixing and conveying equipment

35. — *Approval.* — Before depositing concrete, débris shall be removed from the space to be occupied by the concrete; forms shall be thoroughly wetted (except in freezing weather), or oiled. Reinforcement shall be thoroughly secured in position and approved by the engineer.

36. — *Handling.* — Concrete shall be handled from the mixer to the place of final deposit as rapidly as practicable by methods which shall prevent the separation or loss of the ingredients. It shall be deposited in the forms as nearly as practicable in its final position to avoid rehandling. It shall be deposited in approximately uniform horizontal layers; the piling up of the concrete in the forms in such manner as to permit the escape of the mortar from the coarse aggregate will not be permitted. Forms for walls or other thin section of considerable height, shall be provided with openings, or other devices which will permit the concrete to be placed in a manner that will avoid accumulations of hardened concrete on forms or metal reinforcement. Under no circumstances shall concrete that has partly hardened be deposited in the work.

37. — *Spouting.* — Where concrete is conveyed by spouting, the plant shall be of such size and design as to ensure a practically continuous flow in the spout. The angle of the spout with the horizontal shall be such as to allow the concrete to flow without separation of the ingredients (1). The spout shall be thoroughly flushed with water before and after each run. The delivery from the spout shall be as close as possible to the point of deposit. When operation must be intermittent, the spout shall discharge into a hopper.

38. — *Compacting.* — Concrete, during and immediately after depositing, shall be thoroughly compacted by means of rods or forks. For thin walls or inaccessible portions of the forms where rodding or forking is impracticable, the concrete shall be assisted into place by tapping or hammering the forms. The concrete shall be thoroughly worked around the reinforcement, and around embedded fixtures, into the corners of the forms.

---

(1) An angle of about 27°, or one vertical to two horizontal, is good practice. Spouting through a vertical pipe is satisfactory when the flow is continuous; when it is unchecked and discontinuous it is highly objectionable unless the flow is broken by baffles.

39. — *Removal of water.* — Water shall be removed from excavations before concrete is deposited, unless otherwise directed by the engineer. A continuous flow of water into the excavation shall be diverted through proper side-drains to a sump, or by other approved methods which will avoid washing the freshly deposited concrete.

40. — *Protection.* — Exposed surfaces of concrete subjected to premature drying shall be kept thoroughly wetted for a period of at least 7 days.

41. — *Cold weather.* — Concrete mixed and deposited during freezing weather shall have a temperature of not less than 50° Fahr., nor more than 100° Fahr. Suitable means shall be provided for maintaining a temperature of at least 50° Fahr. for not less than 72 hours after placing, or until the concrete has thoroughly hardened. The methods of heating the materials and protecting the concrete shall be approved by the engineer. Salt, chemicals, or other foreign materials shall not be used to prevent freezing.

42. — *Depositing continuously.* — Concrete shall be deposited continuously and as rapidly as practicable and until the unit of operation, as approved by the engineer, is completed. Construction joints at points not provided for in the plans, shall be made in accordance with the provisions in section 69.

43. — *Bonding.* — The surface of the hardened concrete shall be roughened and thoroughly cleaned of foreign matter and laitance, and saturated with water and forms retightened before depositing concrete. An excess of mortar on vertical or inclined surfaces shall be secured by thoroughly rodding or forking the freshly deposited concrete to remove the coarse aggregate from contact with the hardened concrete.

B. — Rubble and cyclopean concrete.

44. — *Rubble concrete.* — Rubble aggregate shall be thoroughly embedded in the concrete. The individual stones shall not be closer to any surface or adjacent stone than the maximum size of the coarse aggregate plus 1 inch. Each successive layer of concrete shall be keyed in accordance with the provision in section 69.

45. — *Cyclopean concrete.* — Cyclopean aggregate shall be thoroughly embedded in the concrete; no stone shall be closer to a finished surface than 1 foot, nor closer than 6 inches to any adjacent stone. Stratified stone shall be laid on its natural bed.

C. — Depositing under water [1].

46. — *General.* — The methods, equipment, and materials to be used shall be submitted to and approved by the engineer before the work is started. Concrete shall be deposited by a method that will prevent the washing of the cement from the mixture, minimize the formation of laitance, and avoid flow of water until the concrete has fully hardened. Concrete shall be placed so as to minimize segregation of materials. Hand-mixing will not be permitted. Con-

(1) Concrete should not be deposited under water if practicable to deposit in air. There is always uncertainty as to the results obtained from placing concrete under water; where conditions permit, the additional expense and delay of avoiding this method will be warranted. It is especially important that the aggregate be free from loam and other material which may cause laitance. Washed aggregates are preferable. Coarse aggregate consisting of washed gravel of a somewhat smaller size used in open-air concrete work will give the best results. Concrete should never be deposited under water without experienced supervision. Many failures, especially of structures in sea water, can be traced directly to ignorance of proper methods or lack of expert supervision.

crete shall not be placed in water at temperatures below 35° Fahr.

47. — *Proportions.* — Concrete deposited under water shall consist of not less than 1 part of Portland cement to 6 parts of fine and coarse aggregate, measured separately.

48. — *Coffer-dams.* — Coffer-dams shall be sufficiently tight to prevent flow of water through the space in which concrete is to be deposited. Pumping will not be permitted while concrete is being deposited, nor until it has fully hardened.

49. — *Depositing continuously.* — Concrete shall be deposited continuously, keeping the top surface as nearly level as possible, until it is brought above water, or to the required height. The work shall be carried on with sufficient rapidity to insure bonding of the successive layers.

50. — *Method.* — The following method (1) shall be used for depositing concrete under water :

a) Tremie. — The tremie shall be water-tight and sufficiently large to permit a free flow of concrete. It shall be kept filled (2) at all times during depositing. The concrete shall be discharged and spread by raising the tremie in such manner as to maintain as nearly as practicable a uniform flow and avoid dropping the concrete through water. If the charge is lost during depositing the tremie shall be withdrawn and refilled.

b) Drop-bottom bucket. — The bucket shall be of a type that cannot be dumped until it rests on the surface upon which the concrete is to be deposited. The bottom doors when tripped shall open freely downward and outward. The top of the bucket shall be open. The bucket shall be completely filled, and slowly lowered to avoid back-wash. When discharged, the bucket shall be withdrawn slowly until clear of the concrete.

c) Bags. — Bags of jute or other coarse cloth shall be filled about two-thirds full of concrete and carefully placed by hand in a header-and-stretcher system so that the whole mass is interlocked.

51. — *Laitance.* — The concrete shall be disturbed as little as possible while it is being deposited, in order to avoid the formation of laitance. Laitance shall be removed.

CHAPTER VII.

Forms.

52. — *General.* — Forms shall conform to the shape, lines, and dimensions of the concrete as called for on the plans. Lumber used in forms for exposed surfaces shall be dressed to a uniform thickness, and shall be free from loose knots or other defects. Joints in forms shall be horizontal or vertical. For unexposed surfaces and rough work, undressed lumber may be used. Lumber once used in forms shall have nails withdrawn, and surfaces to be in contact with concrete thoroughly cleaned, before being used again.

53. — *Design.* — Forms shall be substantial and sufficiently tight to prevent leakage of mortar; they shall be properly braced or tied together so as to maintain position and shape. If adequate foundation for shores cannot be secured, trussed supports shall be provided.

54. — *Workmanship.* — Bolts and rods

(1) The engineer should strike out the method or methods inapplicable to the work.

(2) The tremie may be filled by one of the following methods : 1° place the lower end in a box partly filled with concrete, so as to seal the bottom, then lower into position; 2° plug the tremie with cloth sacks or other material, which will be forced down as the tube is filled with concrete; 3° plug the end of the tremie with cloth sacks filled with concrete.

shall preferably be used for internal ties; they shall be so arranged that when the forms are removed no metal shall be within 1 inch of any surface. Wire ties will be permitted only on light and unimportant work; they shall not be used through surfaces where discoloration would be objectionable. Shores supporting successive stories shall be placed directly over those below, or so designed that the load will be transmitted directly to them. Forms shall be set to line and grade and so constructed and fastened as to produce true lines. Special care shall be used to prevent bulging.

55. — *Mouldings.* — Unless otherwise specified, suitable mouldings or bevels shall be placed in the angles of forms to round or bevel the edges of the concrete.

56. — *Oiling.* — The inside of forms shall be coated with non-staining mineral oil, or other approved material, or thoroughly wetted (except in freezing weather). Where oil is used, it shall be applied before the reinforcement is placed.

57. — *Inspection of forms.* — Temporary openings shall be provided at the base of column and wall forms, and other places where necessary, to facilitate inspection and cleaning immediately before depositing concrete.

58. — *Removal of forms.* — Forms shall not be disturbed until the concrete has adequately hardened, nor shall the permanent shores be removed until the structure has attained its full design strength (1) and all excess construction load has been removed. Wall and column forms shall be left in place until the concrete has hardened sufficiently to sustain its own weight and the construction loads likely to come upon it. Forms other than wall or column forms shall be left in place until the concrete has hardened sufficiently to carry the full load which it must sustain, unless removed in sections and each section of the structure is immediately re-shored.

(1) Many conditions affect the hardening of concrete, and the proper time for the removal of the forms should be determined by a competent and responsible person.

CHAPTER VIII.

Details of construction.

A. — Metal reinforcement.

59. — *Cleaning.* — Metal reinforcement, before being positioned, shall be thoroughly cleaned of mill and rust scale, and of coatings of any character that will destroy or reduce the bond. Reinforcement appreciably reduced in section shall be rejected. Reinforcement shall be re-inspected and when necessary cleaned where there is delay in depositing concrete.

60. — *Bending.* — Reinforcement shall be carefully formed to the dimensions indicated on the plans or called for in the specifications. The radius of bends shall be four or more times the least diameter of the reinforcement bar.

61. — *Straightening.* — Metal reinforcement shall not be bent or straightened in a manner that will injure the material. Bars with kinks or bends shall not be used.

62. — *Placing.* — Metal reinforcement shall be accurately positioned, and secured against displacement by using annealed iron wire of not less than No. 18 gauge, or suitable clips at intersections, and shall be supported by concrete or metal chairs, or spacers, or by metal hangers. Parallel bars shall not be placed closer in the clear than 1 1/2 times the diameter of round bars or 1 1/2 times the diagonal of square bars; if the ends of bars are hooked as specified in sec-

tion 130, the clear spacing may be made equal to the diameter of the round bars or to the diagonal of square bars, but in no case shall the spacing between bars be less than 1 inch, nor less than 1 1/4 times the maximum size of the coarse aggregate.

63. — *Splicing* — Splices of tensile reinforcement at points of maximum stress shall be avoided. Splices, where required, shall provide sufficient lap to transfer the stress between bars by bond and shear, or by a mechanical connection such as a screw coupling.

64. — *Offsets in column reinforcement.* — Vertical reinforcement shall be offset in a region where lateral support is afforded when changes in column cross-section occur and the vertical reinforcement bars are not sloped for the full length of the column.

65. — *Future bonding.* — Exposed reinforcement bars intended for bonding with future extensions shall be protected from corrosion.

B. — **Concrete covering over metal.**

66. — *Moisture protection.* — Metal reinforcement in wall footings and column footings shall have a minimum covering of 3 inches of concrete.

67. — *Fire protection.* — Metal reinforcement in fire-resistive construction shall be protected by not less than 1 inch of concrete in slabs and walls, and not less than 2 inches in beams, girders, and columns, provided aggregate showing an expansion not materially greater than that of limestone or trap rock is used; when impracticable to obtain aggregate of this grade, the protective covering shall be 1 inch thicker and shall be reinforced with metal mesh not exceeding 3 inches in greatest dimensions, placed 1 inch from the finished surface.

The metal reinforcement in structures containing incombustible materials and in bridges where the fire hazard is limited, shall be protected by not less than 3/4 inch of concrete in slabs and walls and of not less than 1 1/2 inches in beams, girders, and columns.

68. — *Plaster.* — Plaster finish on an exposed concrete surface may be allowed to reduce the thickness of concrete protection called for in section 67, by half the thickness of the plaster, but the protection shall not be less than that specified in sections 66 and 67.

C. — **Joints.**

69. — *Construction joints.* — Construction joints not indicated on the plans nor specified shall be located and formed so as to least impair the strength and appearance of the structure. Horizontal construction joints shall be formed by embedding stones projecting above the surface, or by roughening the surface in contact, or by mortises or keys formed in the concrete. Sufficient section shall be provided in horizontal as well as vertical keys to resist shear.

70. — *Joints in columns.* — Construction joints in columns shall be made at the under side of the floor. Haunches and column capitals shall be considered as part of, and built monolithic with, the floor construction.

71. — *Joints in floors.* — Construction joints in floors shall be located near the center of spans of slabs, beams, and girders, unless a beam intersects a girder at this point, in which case the joints in the girders shall be offset a distance equal to twice the width of the beam. Adequate provision shall be made for shear either by sufficient reinforcement, or by sloping the joint so as to provide an inclined bearing.

72. — *Monolithic construction.* — Girders and beams designed to be monolithic with walls and columns shall not be

cast until 2 hours after the completion of the walls or columns.

73. — *Construction joints in long buildings.* — Construction joints made crosswise of a building 100 feet or more in length, shall have special reinforcement placed at right angles to the joint and extending a sufficient distance on each side of the joint to develop the strength of the reinforcement by bond. This reinforcement shall be placed near the opposite face of the member from the main tension reinforcement; the amount of such reinforcement shall be not less than 0.5 % of the section of the members cut by the joint.

74. — *Expansion joints.* — Expansion joints shall be so detailed that the necessary movement may occur with the minimum of resistance at the joint. The structure adjacent to the joint shall preferably be supported on separate columns or walls. Reinforcement shall not extend across an expansion joint. The break between the two sections shall be complete, and may be effected by a coating of white lead and oil, asphalt paint or petrolatum, or by building paper, placed over the entire surface of the hardened concrete. Exposed edges of expansion joints in walls or abutments shall be bonded. Exposed expansion joints formed between two distinct concrete members shall be filled with an elastic filler of approved quality.

75. — *Expansion joints in long buildings.* — Structures exceeding 200 feet in length and of width less than about one-half the length, shall be divided by means of expansion joints, located near the middle, but not more than 200 feet apart, to minimize the destructive effects of temperature changes and shrinkage. Structures in which marked changes in plan section take place abruptly, or within a small distance, shall be provided with expansion joints at the points where such changes in section occur.

76. — *Sliding joints.* — The seat of sliding joints shall be finished with a smooth troweled surface and shall not have the superimposed concrete placed upon it until it has thoroughly hardened. In order to facilitate sliding, two thicknesses of building paper shall be placed over the seat on which the superimposed concrete is to be deposited.

77. — *Water-tight joints.* — When it is not possible to finish a section of the structure in one continuous operation and water-tight construction is required, the joints shall be prepared as follows : the surface of the first section of concrete shall be provided with continuous keyways. All laitance and other foreign substances shall be removed from the surface of the concrete first placed; this surface shall then be thoroughly saturated with water and given a heavy coating of neat cement. The next section of concrete shall be placed in such manner as to insure an excess of mortar over the entire surface on the joint. Where shown on the plans, the joint shall be so constructed as to permit of its being caulked with oakum.

CHAPTER IX.

Water-proofing and protective treatment.

A. — Water-proofing.

78. — *General.* — The requirements for quality of concrete in section 28 shall be strictly followed. Particular attention shall be given to workmanship.

79. — *Integral compounds.* — Integral compounds shall not be used.

80. — *Membrane water-proofing.* — Membrane water-proofing shall be used in basements, pits, shafts, tunnels, bridge floors, retaining walls, and similar struc-

tures, where an added protection is desired.

81. — *Water-tight joints.* — See section 77.

B. — **Oil-proofing.**

82. — Concrete structures for containing light mineral oils, animal oils, certain vegetable oils, and other commercial liquids shall be given a special coating which shall be applied immediately after construction. Floors or other surfaces exposed to heavy concentrations of such oils or liquids shall be similarly protected. The treatment to be applied shall be approved by the engineer.

C. — **Concrete in sea water.**

83. — *Proportions.* — Plain concrete in sea water or exposed directly along the sea coast shall contain not less than 1 1/2 bbl. (6 bags) of Portland cement per cubic yard in place; concrete from 2 feet below low water to 2 feet above high water, or from a plane below to a plane above wave action, shall be made of a mixture containing not less than 1 3/4 bbl. (7 bags) of Portland cement per cubic yard in place. Slag, broken brick, soft limestone, soft sandstone, or other porous or weak aggregates shall not be used.

84. — *Depositing.* — Concrete shall not be deposited under sea water, unless unavoidable, in which case it shall be placed in accordance with the methods described in sections 48 to 51. Sea water shall not be allowed to come in contact with the concrete until it has hardened for at least 4 days. Concrete shall be placed in such a manner as to avoid horizontal or inclined seams or work planes. The placing of concrete between tides shall be a continuous operation, in accordance with the methods described in section 42; where it is impossible to avoid seams or joints, proceed as in section 43.

85. — *Protection.* — Metal reinforcement shall be placed at least 3 inches from any plane or curved surface, and at corners at least 4 inches from all adjacent surfaces. Metal chairs, supports, or ties shall not extend to the surface of the concrete. Where unusually severe conditions of abrasion are anticipated, the face of the concrete from 2 feet below low water to 2 feet above high water, or from a plane below to a plane above wave action, shall be protected by creosoted timber, dense vitrified shale brick, or stone of suitable quality, as designated on the plans.

86. — *Consistency.* — The consistency shall be such as to produce concrete which for mass work shall give a slump of not more than 2 inches, and for reinforced concrete a slump of not more than 4 inches.

D. — **Concrete in alkali soils or water.**

87. — *Proportions.* — Concrete below the ground-line shall contain not less than 1 3/4 bbl. (7 bags) of Portland cement per cubic yard in place.

88. — *Consistency.* — The consistency of the concrete shall be such as to produce a slump of not more than 2 inches, and for small members in which aggregates coarser than 3/8 inch cannot be used, a slump of not more than 6 inches.

89. — *Placing.* — Concrete shall be placed in such a manner as to avoid horizontal, or inclined seams, or work planes; where this is impossible the requirements of section 69 shall be followed.

90. — *Curing.* — Concrete shall be kept wet with fresh water for not less than 7 days following placing.

91. — *Protection.* — Metal reinforce-

ment or other corrodible metal shall not be placed closer than 2 inches to the exposed faces of members exposed to alkali soil or water.

CHAPTER X.

Surface finish

92. — *General.* — Concrete to have exposed surfaces with specified finish shall be mixed, placed and worked to secure a uniform distribution of the aggregates, and insure uniform texture of surface (1). Placing shall be continuous throughout each distinct division of an area. Joint lines shall be located at indicated points. Voids which appear upon removal of the forms shall be drenched with water and be immediately filled with material of the same composition as that used in the surface, and smoothed with a wood spatula or float. Fins or offsets shall be neatly removed. The work shall be finished free from streaks.

93. — *Top surfaces not subject to wear.* — Top surfaces not subject to wear shall be smoothed with a wood float and be kept wet for at least 7 days. Care shall be taken to avoid an excess of water in the concrete, and to drain off or otherwise promptly remove any water that comes to the surface. Dry cement, or a dry mixture of cement and sand, shall not be sprinkled directly on the surface.

A. — Wearing surfaces.

94. — *One course work.* — Aggregates for the wearing surface shall have a high resistance to abrasion. They shall be carefully screened and thoroughly washed. The least quantity of mixing water that will produce a dense concrete shall be used. The mix shall not be leaner than 1 part of Portland cement to 2 1/2 parts of aggregate. The surface shall be screeded even and finished with a wood float. Excess water shall be promptly drained off or otherwise removed. Overtroweling shall be avoided.

95. — *Two-course work.* — In two-course work the wearing surface shall be placed within 1/2 hour after the base course.

If the wearing surface is required to be applied to a hardened base course, the latter shall be prepared by roughening with a pick or other effective tool, thoroughly drenching with water until saturated, and covered with a thin layer of neat cement immediately before the wearing surface is placed.

The finished wearing course in two-course work shall not be thinner than 1 inch.

96. — *Curing.* — Concrete wearing surfaces constructed in accordance with sections 94 and 95, shall be kept wet (1) for at least 10 days in the case of floors and 21 days in the case of roads and pavements.

97. (2) — *Terrazzo finish.* — Terrazzo finish shall be constructed by mixing 1 part of Portland cement, 2 1/2 parts of crushed marble which will pass through a 1/2-inch screen and is free from dust, and sufficient water to produce a dense

---

(1) This is accomplished by uniform proportioning of ingredients and thorough mixing with the proper quantity of water; after placing, the concrete should be thoroughly rodded or forked to force the aggregate against the face forms and prevent the formation of voids.

(1) Prevention of premature drying during the early hardening of concrete is essential to the development of high resistance to abrasion. The surface may be covered with a layer of burlap, earth, or sand, kept wet, or it may be divided into small areas by dikes and flooded with water to a depth of 2 or 3 inches.

(2) The engineer should strike out one of the two sections numbered 97.

concrete, which shall be spread on the base course and worked down to a thickness of 1 inch by patting or rolling and troweling.

The surface shall be kept wet for not less than 10 days and after thoroughly curing shall be rubbed to a plane surface with a stone or a surfacing machine. Hardened concrete to which a terrazzo finish is to be applied shall be prepared as prescribed in section 95.

97 [1]. — *Terrazzo finish.* — Terrazzo finish shall be constructed by mixing 1 part of Portland cement, 2 parts of sand, and sufficient water to produce a plastic mortar, which shall be spread on the base course to a depth of 1 inch Crushed marble, which will pass through a 1/4 inch screen and is free from dust, shall be sprinkled over the surface of the fresh mortar and pressed or rolled in.

The surface shall be kept wet for not less than 10 days and after thoroughly curing shall be rubbed to a plane surface with a stone or a surfacing machine. Hardened concrete to which a terrazzo finish is to be applied shall be prepared as prescribed in section 95.

B. — Decorative finishes.

98. — *Rubbed finish.* — Concrete shall be wetted immediately after the forms are removed and rubbed even and smooth with a carborundum brick, or other abrasive, and to uniform appearance without applying any cement or other coating.

99. — *Scrubbed finish.* — The face forms shall be removed as soon as the concrete has hardened sufficiently. Voids shall be immediately filled with mortar of the same composition as that used in the face. Fins and other unevennesses shall be rubbed off and the whole surface be scrubbed with fiber or wire brushes, using water freely, as the degree of hardness may require, until the aggregate is uniformly exposed; the surface shall then be rinsed with clean water. The corners shall be sharp and unbroken. If portions of the surface have become too hard to scrub in uniform relief, dilute hydrochloric acid (1 part of acid to 4 parts of water) may be used to facilitate scrubbing of hardened surfaces. The acid shall be thoroughly washed off with clean water.

100. — *Sand-blast finish.* — Immediately following removal of forms, voids shall be filled with mortar of the same composition as that used in the face, and allowed to harden. Unevennesses and form marks shall be removed by chipping or rubbing; the face shall then be cut with an air blast of hard sand with angular grains until the aggregate is in uniform relief.

101. — *Tooled finish.* — The surface shall be permitted to become hard and dry before tooling. The cutting shall remove the entire skin and produce a uniform surface true to lines.

102. — *Sand-floated finish.* — The forms shall be removed before the surface has fully hardened; the surface shall be rubbed with a wooden float by a uniform circular motion, using fine sand until the resulting finish is even and uniform.

103. — *Colored aggregate finish.* — Colored or other special aggregate used for finish shall be exposed by scrubbing as provided in section 99. Facing mortar of 1 part of Portland cement 1 1/2 parts of sand, and 3 parts of screenings or pebbles shall be placed against the face forms to a thickness of about 1 inch sufficiently in advance of the body concrete to prevent the latter coming in contact with the form.

104. — *Colored pigment finish.* — Mineral pigment shall be thoroughly mixed dry with the Portland cement and fine

---
[1] The engineer should strike out one of the two sections numbered 97.

aggregate; care shall be taken to secure a uniform tint throughout.

CHAPTER XI.

Design.

A. — General assumptions.

105. — The design of reinforced concrete members under these specifications shall be based on the following assumptions :

a) Calculations are made with reference to working stresses and safe loads rather than with reference to ultimate strength and ultimate loads.

b) A plane section before bending remains plane after bending.

c) The modulus of elasticity of concrete in compression is constant within the limits of working stresses; the distribution of compressive stress in beams is therefore rectilinear.

d) The values for the modulus of elasticity of concrete in computations for the position of the neutral axis, for the resisting moment of beams, and for compression of concrete in columns, are as follows :

1° One-fortieth (1/40) that of steel, when the compressive strength of the concrete at 28 days is below 800 lb. per square inch;

2° One-fifteenth (1/15) that of steel, when the compressive strength of the concrete at 28 days lies between 800 and 2 200 lb. per square inch;

3° One-twelfth (1/12) that of steel, when the compressive strength of the concrete at 28 days lies between 2 200 and 2 900 lb. per square inch;

4° One-tenth (1/10) that of steel, when the compressive strength of the concrete at 28 days is higher than 2 900 lb. per square inch;

5° One-eighth (1/8) that of steel for calculating the deflection of reinforced concrete beams which are free to move longitudinally at the supports, and in which the tensile resistance of the concrete is neglected.

e) In calculating the moment of resistance of reinforced concrete beams and slabs the tensile resistance of the concrete is neglected.

f) The adhesion between the concrete and the metal reinforcement remains unbroken throughout the range of working stresses. Under compression the two materials are therefore stressed in proportion to their moduli of elasticity.

g) Initial stress in the reinforcement due to contraction or expansion of the concrete is neglected, except in the design of reinforced concrete columns.

B. — Flexure of rectangular reinforced concrete beams and slabs.

106. — *Flexure formulas.* — Computations of flexure in rectangular reinforced concrete beams and slabs shall be based on the following formulas :

a) *Reinforced for tension only :*

Position of neutral axis,

$$k = \sqrt{2\,pn + (pn)^2} - pn. \quad . \quad . \quad (1)$$

Arm [1] of resisting couple,

$$j = 1 - \frac{k}{3} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Compressive unit stress [1] in extreme fiber of concrete,

$$f_c = \frac{2\,M}{jkbd^2} = \frac{2\,pf_s}{k} \quad . \quad . \quad . \quad . \quad (3)$$

Tensile unit stress [1] in longitudinal reinforcement,

$$f_s = \frac{M}{A\,jd} = \frac{M}{pjbd^2} \quad . \quad . \quad . \quad . \quad (4)$$

[1] For $f_s = 16\,000$ to $18\,000$ lb. per square inch and $f_c = 800$ to 900 lb. per square inch, j may be assumed as 0.86. For values of pn varying from 0.04 to 0.24, jk is approximately equal to $0.67\sqrt[3]{pn}$.

Steel ratio for balanced reinforcement,

$$p = \frac{1}{2} \frac{1}{\frac{f_s}{f_c}\left(\frac{f_s}{nf_c} + 1\right)} \quad . \ . \ . \ . \ . \quad (5)$$

For formulas on shear and bond, see sections 120 and 140.

b) Reinforced for both tension and compression :

Position of neutral axis,

$$k = \sqrt{2n\left(p + p'\frac{d'}{d}\right) + n^2(p + p')^2} - n(p + p') \quad . \ . \ . \ . \ . \ . \quad (6)$$

Position of resultant compression,

$$z = \frac{\frac{1}{3}k^3 d + 2p'nd'\left(k - \frac{d'}{d}\right)}{k^2 + 2p'n\left(k - \frac{d'}{d}\right)} \quad . \ . \quad (7)$$

Arm of resisting couple,

$$jd = d - z \quad . \ . \ . \ . \ . \ . \ . \quad (8)$$

Compressive unit stress in extreme fiber of concrete,

$$f_c = \frac{6\,M}{bd^2\left[3k - k^2 + \frac{6p'n}{k}\left(k - \frac{d'}{d}\right)\left(1 - \frac{d'}{d}\right)\right]} \quad (9)$$

Tensile unit stress in longitudinal reinforcement,

$$f_s = \frac{M}{pjbd^2} = nf_c\frac{1-k}{k} \quad . \ . \ . \quad (10)$$

Compressive unit stress in longitudinal reinforcement,

$$f'_s = nf_c\frac{k - \frac{d'}{d}}{k} \quad . \ . \ . \ . \ . \quad (11)$$

107. — *Notation.* — The symbols used in formulas 1 to 23 are defined as follows :

A_s = effective cross-sectional area of metal reinforcement in tension in beams;

b = width of rectangular beam, or width of flange of T-beam;

d = depth from compression surface of beam or slab to center of longitudinal tension reinforcement;

d' = depth from compression surface of beam or slab to center of compression reinforcement;

f_c = compressive unit stress in extreme fiber of concrete;

f_s = tensile unit stress in longitudinal reinforcement;

f'_s = compressive unit stress in longitudinal reinforcement;

h = unsupported length of column;

I = moment of inertia of a section about the neutral axis for bending;

j = ratio of lever arm of resisting couple to depth, d;

k = ratio of depth of neutral axis to depth, d;

l = span length of beam or slab (generally distance from center to center of supports, see section 108);

M = bending moment or moment of resistance in general;

n = $\frac{E_s}{E_c}$ = ratio of modulus of elasticity of steel to that of concrete;

p = ratio of effective area of tension reinforcement to effective area of concrete in beams = $\frac{A_s}{bd}$;

p' = ratio of effective area of compression reinforcement to effective area of concrete in beams;

w = uniformly distributed load per unit of length of beam or slab;

z = depth from compression surface of beam or slab to resultant of compressive stresses.

108. — *Span length.* — The span length, l, of freely supported beams and slabs shall be the distance between centers of the supports, but shall not exceed the clear span plus the depth of beam or slab. The span length for continuous or restrained beams built monolithically

with supports shall be the clear distance between faces of supports. Where brackets having a width not less than the width of the beam, and making an angle of 45° or more with the axis of a restrained beam are built monolithic with the beam and support, the span shall be measured from the section where the combined depth of the beam and bracket is at least one-third more than the depth of the beam. Maximum negative moments are to be considered as existing at the ends of the span, as above defined. No portion of a bracket shall be considered as adding to the effective depth of the beam.

109. — *Moments in freely supported beams of equal span.* — The following moments at critical sections of freely supported beams and slabs of equal spans carrying uniformly distributed loads shall be used :

a) Maximum positive moment in beams and slabs of one span,

$$M = \frac{wl^2}{8} \quad \dots\dots\dots \quad (12)$$

b) Center of slabs and beams continuous for two spans only,

1° Positive moment at the center,

$$M = \frac{wl^2}{10} \quad \dots\dots\dots \quad (13)$$

2° Maximum negative moment,

$$M = \frac{wl^2}{8} \quad \dots\dots\dots \quad (14)$$

c) Slabs and beams continuous for more than two spans,

1° Center and supports of interior spans,

$$M = \frac{wl^2}{12} \quad \dots\dots\dots \quad (15)$$

2° Center and interior support of end spans,

$$M = \frac{wl^2}{10} \quad \dots\dots\dots \quad (16)$$

d) Negative moment at the supports of slab or beam built into brick or masonry walls in a manner that develops partial end restraint,

$$M = \text{not less than } \frac{wl^2}{16} \quad \dots \quad (17)$$

110. — *Moments in beams monolithic with supports.* — The following moments at the critical sections of beams or slabs of equal spans cast monolithic with columns or similar supports, and carrying uniformly distributed loads shall be used :

a) Supports of intermediate spans,

$$M = \frac{wl^2}{12} \quad \dots\dots\dots \quad (18)$$

b) Center of intermediate spans,

$$M = \frac{wl^2}{16} \quad \dots\dots\dots \quad (19)$$

c) Beams in which $\frac{I}{l}$ is less than twice the sum of the value of $\frac{I}{h}$ for the exterior columns above and below, which are built into the beam,

1° Center and first interior support,

$$M = \frac{wl^2}{12} \quad \dots\dots\dots \quad (20)$$

2° Exterior supports,

$$M = \frac{wl^2}{12} \quad \dots\dots\dots \quad (21)$$

d) Beams in wich $\frac{I}{l}$ is equal to, or greater than, twice the sum of the values of $\frac{I}{h}$ for the exterior columns above and below which are built into the beam,

1° Center of span and at first interior support of end span,

$$M = \frac{wl^2}{10} \quad \dots\dots\dots \quad (22)$$

2° Exterior support,

$$M = \frac{wl^2}{16} \quad \dots\dots\dots \quad (23)$$

111. — *Moment coefficients of continuous beams.* — Continuous beams with unequal spans, whether freely supported or cast monolithic with columns, shall be analyzed to determine the actual moments under the given conditions of loading and restraint. Provision shall be made for negative moment occurring in short spans adjacent to longer spans when the latter only are loaded.

C. — Flexure of reinforced concrete T-beams.

112. — *Flexure formulas.* — Computations of flexure in reinforced concrete T-beams shall be based on the following formulas :

a) Neutral axis in the flange :

Use formulas for rectangular beams and slabs in section 106.

b) Neutral axis below the flange (1) :

Position of neutral axis,

$$kd = \frac{2\,nd\mathrm{A}_s + bt^2}{2n\mathrm{A}_s + 2\,bt} \quad . \; . \; . \; . \quad (24)$$

Position of resultant compression,

$$z = \left(\frac{3\,kd - 2\,t}{2\,kd - t}\right)\frac{t}{3} \quad . \; . \; . \; . \quad (25)$$

Arm of resisting couple,

$$jd = d - z \; . \; . \; . \; . \; . \; . \quad (26)$$

Compressive unit stress in extreme fiber of concrete,

$$f_c = \frac{\mathrm{M}kd}{bt\left(kd - \frac{1}{2}t\right)jd} = \frac{f_s}{n}\left(\frac{k}{1 - k}\right) \quad (27)$$

Tensile unit stress in longitudinal reinforcement,

$$f_s = \frac{\mathrm{M}}{\mathrm{A}_s jd} \; . \; . \; . \; . \; . \; . \quad (28)$$

(1) For approximate results the formulas for rectangular beams, section 106, may be used.

Formulas 24, 25, 26, 27, and 28 neglect compression in the stem (1).

113. — *Notation.* — The symbols used in Formulas 24 to 28 are defined in section 107, except as follows :

b' = width of stem of T-beam ;
t = thickness of flanges of T-beam.

114. — *Flange width.* — Effective and adequate bond and shear resistance shall be provided in beam-and-slab construction at the junction of the beam and slab; the slab shall be built and considered an integral part of the beam; the effective flange width shall not exceed one-fourth of the span length of the beam, and its overhanging width on either side of the web shall not exceed 8 times the thickness of the slab nor one-half the clear distance to the next beam.

115. — *Flange length.* — The unsupported length of the compression flange of a T-beam shall not exceed 36 times the least width of the beam.

(1) The following formulas take into account the compression in the stem; they are recommended where the flange is small compared with the stem :

Position of neutral axis,

$$kd = \sqrt{\frac{2\,nd\mathrm{A}_s + (b - b')\,t^2}{b'} + \left(\frac{n\mathrm{A}_s + (b - b')\,t}{b'}\right)^2} - \frac{n\mathrm{A}_s + (b - b')\,t}{b'} \; . \; . \; . \; . \quad (24a)$$

Position of resultant compression,

$$z = \frac{\left(kdt^2 - \frac{2}{3}t^3\right)b + \left[(kd - t)^2\left(t + \frac{1}{3}(kd - t)\right)\right]b'}{t\,(2\,kd - t)\,b + (kd - t)^2\,b'} \quad (25a)$$

Arm of resisting couple (see footnote, section 106),

$$jd = d - z. \; . \; . \; . \; . \; . \; . \quad (26a)$$

Compressive unit stress in extreme fibre of concrete,

$$f_c = \frac{2\,\mathrm{M}kd}{[(2\,kd - t)\,bt + (kd - t)^2\,b']\,jd} \quad (27a)$$

Tensile unit stress in longitudinal reinforcement,

$$f_s = \frac{\mathrm{M}}{\mathrm{A}_s jd} \; . \; . \; . \; . \; . \; . \; . \quad (28a)$$

116. — *Transverse reinforcement.* — Where the principal slab reinforcement is parallel to the beam, transverse reinforcement, not less in amount than 0.3 % of the sectional area of the slab, shall be provided in the top of the slab, and shall extend over the beam and into the slab not less than two-thirds of the effective flange overhang. The spacing of the bars shall not exceed 18 inches.

117. — *Compressive stress in supports.* — Provision shall be made for the compressive stress at the support in continuous T-beam construction.

118. — *Shear.* — The flange of the slab shall not be considered as effective in computing the shear and diagonal tension resistance of T-beams.

119. — *Isolated beams.* — Isolated beams in which the T-form is used only for the purpose of providing additional compression area, shall have a flange thickness not less than one-half the width of the web, and a total flange width not more than 4 times the web thickness.

D. — Diagonal tension and shear.

a) Formulas and notation.

120. — *Formulas.* — Diagonal tension and shear in reinforced concrete beams shall be calculated by the following formulas :

Shearing unit stress [1],

$$v = \frac{V}{bjd} \quad \ldots\ldots\ldots \quad (29)$$

Stress [1] in vertical web reinforcement,

$$f_v = \frac{V's}{A_v jd} \quad \ldots\ldots \quad (30)$$

121. — *Notation.* — The symbols used in formulas 29 to 36 are defined in section 107, except as follows :

a = spacing of web reinforcement bars measured perpendicular to their direction;

A_v = total area of web reinforcement in tension within a distance of a (a_1, a_2, a_3, etc.), or the total area of all bars bent up in any one plane;

α = angle between web bars and longitudinal bars;

f_v = tensile unit stress in web reinforcement;

o = perimeter of bar;

Σ_o = sum of perimeters of bars in one set;

r = ratio of cross-sectional area of negative reinforcement which crosses entirely over the column capital of a flat slab or over the dropped panel, to the total cross-sectional area of the negative reinforcement in the two column strips;

s = spacing of web members, measured at the neutral axis and in the direction of longitudinal axis of the beam;

u = bond stress per unit of area of surface of bar;

v = shearing unit stress;

V = total shear;

V' = external shear on any section after deducting that carried by the concrete.

b) Beams without web reinforcement.

122. — *Bars not anchored.* — The shearing unit stress in beams in which the longitudinal reinforcement is designed to meet all moment requirements, but without special anchorage, shall not exceed $0.02 f'_c$, but in no case shall it exceed 40 lb. per square inch. Adequate reinforcement shall be provided at all sections where negative moment occurs in beams continuous over supports or built into walls or columns at their ends.

---

[1] Approximate results may be secured by assuming $j = 0.875$.

123. — *Bars anchored.* — The shearing unit stress in beams in which longitudinal reinforcement is anchored by means of hooked ends or otherwise, as specified in section 130, shall not exceed $0.03 f'_c$. Adequate reinforcement for both positive and negative moment shall be provided at all sections where maximum moment exists.

c) BEAMS WITH WEB REINFORCEMENT.

124. — *With web reinforcement.* — When the shearing unit stress calculated by formula 29 exceeds the values specified in sections 122 and 123, web reinforcement shall be provided by one or more of the following methods :

a) Series of vertical stirrups or web bars;

b) Series of inclined stirrups or web bars;

c) Series of bent-up longitudinal bars;

d) Longitudinal bars bent up in a single plane.

Provision against bond failure of the web reinforcement shall be as specified in section 131.

125. — *Web or bent-up bars.* — Where web reinforcement is present and where longitudinal reinforcement is provided to meet all moment requirements, the concrete may be assumed to carry a shearing unit stress not greater than $0.02 f'_c$ and not greater in any case than 40 lb. per square inch. In the case where a series of web bars or bent-up longitudinal bars is used, the web reinforcement shall be designed according to the formula :

$$A_v = \frac{V'a}{f_v jd} = \frac{V's \sin\alpha}{f_v jd} \quad . \; . \; . \quad (31)$$

126. — *Bars bent up in single plane.* — Where the web reinforcement consists of bars bent up in a single plane at an angle so as to reinforce all sections of the beam in which the shearing unit stress on the web concrete exceeds $0.02 f'_c$, the concrete may be assumed to take a shearing unit stress not greater than $0.02 f'_c$, and not greater than 40 lb. per square inch; the remainder of the shear shall be carried by the bent-up bars designed according to the formula :

$$A_v = \frac{V'}{f_v \sin\alpha} \quad . \; . \; . \; . \; . \quad (32)$$

In case the web reinforcement consists solely of bent bars, the first bent bar shall bend downward from the plane of the upper reinforcement at the plane of the edge of the support or between that plane and the center of the support.

127. — *Combined web reinforcement.* — Where two or more types of web reinforcement are used in conjunction, the total shearing resistance of the beam shall be taken as the sum of the shearing resistances as computed for the various types separately (1).

128. — *Maximum shearing unit stress.* — Where there is no special mechanical anchorage of the longitudinal reinforcement, the shearing unit stress shall not exceed $0.06 f'_c$, irrespective of the web reinforcement used.

129. — *Special mechanical anchorage.* — Where special mechanical anchorage of the longitudinal reinforcement as prescribed in section 130 is provided, the shearing unit stress as computed by formula 29, may be greater than $0.06 f'_c$, but in no case shall it exceed $0.12 f'_c$ (2). In this case the concrete may be assumed to take a shearing unit stress of not

(1) In such computation the shearing value of the concrete in the web shall be included once only.

(2) The limit, $0.12 f'_c$, is based on the ultimate bearing unit stress of $0.5 f'_c$ at which beams reinforced with vertical stirrups fail due to diagonal compression in the webs. A higher value than $0.12 f'_c$ may be permitted in beams with inclined web reinforcement, but it is not thought necessary to allow such higher limit to meet the needs of design practice.

more than $0.025 f'_c$, but not more than 50 lb. per square inch.

130. — *Anchorage of longitudinal reinforcement.* — Special mechanical anchorage of the longitudinal reinforcement for positive moment may consist of carrying the bars a sufficient distance beyond the point of inflection of restrained or continuous members to develop by bond between the point of inflection and the end of the bar a tensile stress equal to one-third the safe working stress in the reinforcement. If such a bar is straight, it shall extend to within 1 inch of the center of the support, or in the case of wide supports shall extend not less than 12 inches beyond the face of the support. Special mechanical anchorage may also be secured by bending the end of the bar over the support in a full semi-circle to a diameter not less than 8 times the diameter of the bar, the total length of the bend being not less than 16 diameters of the bar. Any other mechanical device that secures the end of the bar over the support against slipping without stressing the concrete in excess of $0.5 f'_c$ in local compression may be used, provided such device does not tend to split the concrete. Negative reinforcement shall be thoroughly anchored at or across the support, or shall extend into the span a sufficient distance to develop by bond the tensile stresses due to negative moment. In the case of freely supported ends of continuous beams, special mechanical anchorage shall be provided, which is capable of developing at the end of the span a tensile stress which is not less than one-third of the safe tensile stress of the bar at the point of maximum moment.

131. — *Anchorage of web reinforcement.* — Anchorage of the web reinforcement shall be by one of the following methods :

a) Continuity of the web bar with the longitudinal bar;

b) Carrying the web bar around at least two sides of a longitudinal bar at both ends of the web bar; or

c) Carrying the web bar about at least two sides of a longitudinal bar at one end and making a semi-circular hook at the other end which has a diameter equal to that of the web bar.

In all cases the bent ends of web bars shall extend at least 8 diameters below or above the point of extreme height or depth of the web bar. In case the end anchorage of the web member is not in bearing on other reinforcement, the anchorage shall be such as to engage an adequate amount of concrete to prevent the bar from pulling off a portion of the concrete. In all cases the stirrups shall be carried as close to the upper and lower surfaces as fire-proofing requirements will permit.

132. — *Size of web bars.* — The size of web reinforcing bars which are neither a part of the longitudinal bars nor welded thereto shall be such that not less than two-fifths of the allowable tensile stress in the bar may be developed by bond stresses in a length of bar equal to $0.4\ d$ (1). The remainder of the tensile stress in the bar shall be provided for by adequate anchorage, as specified in section 131.

133. — *Breadth of beams in shear.* — Shearing unit stress shall be computed on the full width of rectangular beams, on the width of the stem of T-beams, and on the thickness of the web in beams of I-section.

134. — *Shear in beam-and-tile construction.* — The shearing stress in tile-and-concrete-beam construction shall not exceed that in beams or slabs with si-

(1) This condition is satisfied for plain round stirrups when the diameter of the bar does not exceed $\frac{d}{50}$.

milar reinforcement. The width of the effective section for shear, as governing diagonal tension, shall be taken as the thickness of the concrete web plus one-half the thickness of the vertical webs of the tile.

135. — *Spacing of web reinforcement.* — The spacing, a, of web reinforcement bars shall be measured perpendicular to their direction and in a plane parallel to the longitudinal axis of the beam. The spacing shall not exceed 3/4 d in any case where web reinforcement is necessary. Where vertical stirrups are used, or where inclined web bars make an angle more than 60° with the horizontal, the spacing shall not exceed 1/2 d. Where the shearing unit stress exceeds 0.06 f'_c. the spacing of the web reinforcement shall not exceed 1/2 d in any case, nor 1/3 d for vertical stirrups or web reinforcement making an angle more than 60° with the horizontal. The first shear reinforcement member shall cross the neutral axis of the member at a distance from the face of the support, measured along the axis of the beam, not greater than 1/4 d, nor greater than the spacing of web members as determined for a section taken at the edge of of the support. Web members may be placed at any angle between 20° and 90° with the longitudinal bars, provided that if inclined they shall be inclined in such a manner as to resist the tensile stress in the web.

d) Flat slabs.

136. — *Shearing stress.* — The shearing unit shearing stress shall not exceed the value of v in the formula,

$$v = 0.02 f'_c (1 + r) \quad (33)$$

nor in any case shall it exceed 0.03 f'_c.

The unit shearing stress shall be computed on

a) A vertical section which has a depth, in inches, of 7/8 (t_1 — 1 1/2), and which lies at a distance, in inches, of t_1 — 1 1/2 from the edge of the column capital; and

b) A vertical section which has a depth, in inches, of 7/8 (t_2 — 1 1/2), and which lies at a distance, in inches, of t_2 — 1 1/2 from the edge of the dropped panel.

In no case shall r be less than 0.25. Where the shearing stress on section *a*) is being considered, r shall be taken as the proportional amount of reinforcement crossing the column capital; where the shearing stress at section *b*) is being considered, r shall be taken as the proportional amount of reinforcement crossing entirely over the dropped panel.

e) Footings.

137. — *Shear and diagonal tension in footings.* — The shearing stress shall be computed by formula 29. When so computed the stress on the critical section defined below, or on sections outside of the critical section, shall not exceed 0.02 f'_c for footings with straight reinforcement bars, nor 0.03 f'_c for footings in which the reinforcement bars are anchored at both ends by adequate hooks or otherwise, as specified in section 130.

138. — *Critical section of soil footings.* — The critical section for diagonal tension in footings bearing directly on the soil shall be taken on a vertical section through the perimeter of the lower base of a frustum of a cone or pyramid which has a base angle of 45°, and has for its top the base of the column or pedestal and for its lower base the plane of the center of the longitudinal reinforcement.

139. — *Critical section for pile footings.* — The critical section for diagonal tension in footings bearing on piles shall be taken on a vertical section at the inner edge of the first row of piles

entirely outside a section midway between the face of the column or pedestal and the section described in section 138 for soil footings, but in no case outside of the section described in section 138. The critical section for piles not grouped in rows shall be taken midway between the face of the column and the perimeter of the base of the frustum described in section 138.

E. — Bond.

140. — *Formula.* — Bond between concrete and reinforcement bars in reinforced concrete beams and slabs shall be computed by the formula :

$$u = \frac{V}{jd\Sigma o} \quad \ldots\ldots\ldots \quad (34)$$

141. — *Working stress.* — Unless otherwise specified, the reinforcement shall be so proportioned that the bond stress between the metal and the concrete shall not exceed the following :

a) Plain bars,

$$u = 0.04\, f'_c \quad \ldots\ldots \quad (35)$$

b) Deformed bars, meeting the requirements of section 23,

$$u = 0.05\, f'_c \quad \ldots\ldots \quad (36)$$

142. — *Bond in footings.* — The bond stress on a section of a footing shall be computed by formula 34. Only the bars counted as effective in bending shall be considered in computing the number of bars crossing a section. The bond stress computed in this manner on sections at the face of the column or outside the column shall not exceed the value specified in section 141. Special investigation shall be made of bond stresses in footings with stepped or sloping upper surface; maximum stresses may occur at sections near the edges of the footings.

143. — *Reinforcement in two or more directions.* — The permissible bond stress given by formulas 35 and 36 for footings and similar members where reinforcement is required in more than one direction shall be reduced as follows :

a) For two-way reinforcement. ... 25 %
b) For each additional direction ... 10 %

144. — *Anchored bars.* — The bond stresses for bars adequately anchored at both ends by hooks or otherwise, as provided in section 130, may be 1 1/2 times the values specified in section 141. Hooks in footings shall be effectively positioned to insure that they engage a mass of concrete above the plane of the reinforcement.

F. — Flat slabs [1].

145. — *Moments in interior panels.* — The symbols used in formulas 37 to 42 are defined in section 107 except as indicated in sections 145, 148 and 158.

In flat slabs in which the ratio of reinforcement for negative moment in the column strip is not greater than 0.01, the numerical sum of the positive and negative moments in the direction of either side of the panel shall be taken as not less than

$$M_0 = 0.09\, Wl\left(1 - \frac{2}{3}\frac{c}{l}\right)^2 \quad \ldots \quad (37)$$

Where

M_o = sum of positive and negative bending moments in either rectangular direction at the principal design sections of a panel of a flat slab;

c = base diameter of the largest right circular cone which lies entirely within the column (including the capital) whose vertex angle is 90° and whose base is 1 1/2 inches

(1) The requirements for flat slabs in sections 145 to 162, inclusive, apply to two-way and four-way systems of reinforcement. The Committee is not prepared at this time to submit requirements covering other types of flat slabs.

below the bottom of the slab or the bottom of the dropped panel;

l = span length of flat slab, center to center of colums in the rectangular direction, in which moments are considered; and

W = total dead and live load uniformly distributed over a single panel area.

146. — *Principal design sections.* — The principal design sections for critical moments in flat slabs subjected to uniform load shall be taken as follows :

a) Negative moment in middle strip : Extending in a rectangular direction from a point on the edge of panel $\frac{l_1}{4}$ from column center a distance $\frac{l_1}{2}$ toward the center of adjacent column on the same panel edge;

b) Negative moment in column strip : Extending in a rectangular direction along the edge of the panel from a point $\frac{l_1}{4}$ from the center of the column to a point $\frac{c}{2}$ from the center of the same column and thence one-quarter circumference about the column center to the adjacent edge of the panel;

c) Positive moment in middle strip : Extending in a rectangular direction from the center of one edge of a middle strip a distance $\frac{l_1}{2}$ to the center of the other edge of the same strip;

d) Positive moment in column strip : Extending in a rectangular direction from the center of one edge of a column strip a distance $\frac{l_1}{4}$ to the center of the other edge of the same strip.

147. — *Moments in principal design sections.* — The moments in the principal design sections shall be those given in table 3, except as follows :

a) The sum of the maximum negative moments in the two column strips may be greater or less than the values given in table 3 by not more than 0.03 M_0;

b) The maximum negative moment and the maximum positive moments in the middle strip and the sum of the maximum positive moments in the two column strips may each be greater or less than the values given in table 3 by not more than 0.01 M_0.

TABLE 3. — **Moments to be used in design of flat slabs.**

STRIP.	Flat slabs without dropped panels.		Flat slabs with dropped panels.	
	Negative.	Positive.	Negative.	Positive.
Slabs with two-way reinforcement.				
Column strip	0.23 M_0	0.11 M_0	0.25 M_0	0.10 M_0
Two-column strips	0.46 M_0	0.22 M_0	0.50 M_0	0.20 M_0
Middle strip.	0.16 M_0	0.16 M_0	0.15 M_0	0.15 M_0
Slabs with four-way reinforcement.				
Column strip	0.25 M_0	0.10 M_0	0.27 M_0	0.095 M_0
Two-column strips	0.50 M_0	0.20 M_0	0.54 M_0	0.190 M_0
Middle strip.	0.10 M_0	0.20 M_0	0.08 M_0	0.190 M_0

148. — *Thickness of flat slabs and dropped panels.*— The total thickness (1), t_1, of the dropped panel, in inches, or of the slab if a dropped panel is not used, shall be not less than :

$$t_1 = 0.0382\left(1 - 1.44\frac{c}{l}\right) l \sqrt{Rw'\frac{l_1}{b_1}} + 1\,^1/_2 \quad (38)^{(2)}$$

where

R = ratio of negative moment in the two-column strips to M_0; and

w' = uniformly distributed dead and live load per unit of area of floor.

For slabs with dropped panels, the total thickness (1), in inches, at points away from the dropped panel shall be not less than :

$$t_2 = 0.02\, l \sqrt{w'} + 1 \quad . \; . \; . \quad (39)$$

The slab thickness, t_1 or t_2, shall in no case be less than $\frac{l}{32}$ for floor-slabs, and not less than $\frac{l}{40}$ for roof slabs. In determining minimum thickness by formulas 38 and 39, the value of l shall be the panel length center to center of the columns on the long side of the panel, l_1 shall be the panel length on the short side of the panel, and b_1 shall be the width or diameter of dropped panel in the direction of l_1, except that in a slab without dropped panel, b_1 shall be 0.5 l_1.

149. — *Minimum dimensions of dropped panels.* — The dropped panel shall have a length or diameter in each rectangular direction of not less than one-third the panel length in that direction, and a thickness not greater than 1.5 t_2.

150. — *Wall and other irregular panels.* — In wall panels and other panels in which the slab is discontinuous at the edge of the panel, the maximum negative moment one panel length away from the discontinuous edge and the maximum positive moment between shall be taken as follows :

a) Column strip perpendicular to the wall or discontinuous edge, 15 % greater than that given in table 3;

b) Middle strip perpendicular to wall or discontinuous edge, 30 % greater than that given in table 3.

In these strips the bars used for positive moments perpendicular to the discontinuous edge shall extend to the exterior edge of the panel at which the slab is discontinuous.

151. — *Panels with wall beams.* — In panels having a marginal beam on one edge or on each of two adjacent edges, the beam shall be designed to carry the load superimposed directly upon it. If the beam has a depth greater than the thickness of the dropped panel into which it frames, the beam shall be designed to carry, in addition to the load superimposed upon it, at least one-quarter of the distributed load for which the adjacent panel or panels are designed, and each column strip adjacent to and parallel with the beam shall be designed to resist a moment at least one-half as great as that specified in table 3 for a column strip (1). If the beam used has a depth less than the thickness of the dropped panel into which it frames, each column strip adjacent to and parallel with the beam shall be designed to resist the moments specified in table 3 for a column strip. Where there are beams on two opposite edges of the panel, the slab and the beam shall be designed as

(1) The thickness will be in inches regardless of whether l and w' are in feet and pounds per square foot or in inches and pounds per square inch.

(2) The values of R used in this formula are the coefficients of M_0 for negative moment in the two-column strips in table 3, section 147.

(1) In wall columns, brackets are sometimes substituted for capitals or other changes are made in the design of the capital. Attention is directed to the necessity for taking into account the change in the value of c in the moment formula for such cases.

though all the load was carried to the beam.

152. — *Discontinuous panels.* — The negative moments on sections at and parallel to the wall, or discontinuous edge of an interior panel, shall be determined by the conditions of restraint [1].

153. — *Flat slabs on bearing walls.* — Where there is a beam or a bearing wall on the center line of columns in the interior portion of a continuous flat slab, the negative moment at the beam or wall line in the middle strip perpendicular to the beam or wall shall be taken as 30 % greater than the moment specified in table 3 for a middle strip. The column strip adjacent to and lying on either side of the beam or wall shall be designed to resist a moment at least one-half of that specified in table 3 for a column strip.

154. — *Point of inflection.* — The point of inflection in any line parallel to a panel edge in interior panels of symmetrical slabs without dropped panels shall be assumed to be at a distance from the center of the span equal to 3/10 of the distance between the two sections of critical negative moment at opposite ends of the line; for slabs having dropped panels, the coefficient shall be 1/4.

155. — *Reinforcement.* — The reinforcement bars which cross any section and which fulfill the requirements given in section 156 may be considered as effective in resisting the moment at the section. The sectional area of a bar multiplied by the cosine of the angle between the direction of the axis of the bar and any other direction may be considered effective as reinforcement in that direction.

156. — *Arrangement of reinforcement.* — The design shall include adequate provision for securing the reinforcement in place so as to take not only the critical moments, but the moments at intermediate sections. All bars in rectangular or diagonal directions shall extend on each side of a section of critical moment, either positive or negative, to points at least 20 diameters beyond the point of inflection as specified in section 154. In addition to this provision, bars in diagonal direction used as reinforcement for negative moment shall extend on each side of a line drawn through the column center at right angles to the direction of the band at least a distance of 0.35 of the panel length, and bars in diagonal directions used as reinforcement for positive moment shall extend on each side of a diagonal through the center of the panel at least a distance equal to 0.35 of the panel length; no splice by lapping shall be permitted at or near regions of maximum stress except as just described. At least two-thirds of all bars in each direction shall be of such length and shall be so placed as to provide reinforcement at two sections of critical negative moment and at the intermediate section of critical positive moment. Continuous bars shall not all be bent up at the same point of their length, but the zone in which this bending occurs shall extend on each side of the assumed point of inflection, and shall cover a width of at least 1/15 of the panel length. Mere sagging of the bars shall not be permitted. In four-way reinforcement the position of the bars in both diagonal and rectangular directions may be considered in determining whether the width of zone of bending is sufficient.

157. — *Reinforcement at construction joints.* — See section 73.

158. — *Tensile stress in reinforcement.* — The following formula shall be used in computing the tensile stress $\overline{f_s}$ in the reinforcement in flat slabs; the

[1] The Committee is not prepared to make a more definite recommendation at this time.

stress so computed shall not at any of the principal design sections exceed the values specified in section 205 :

$$f_s = \frac{RM_0}{A_s jd} \quad \ldots\ldots \quad (40)$$

Where

RM_0 = moment specified in section 147 for two-column strips or for one middle strip; and

A_s = effective cross-sectional area of the reinforcement which crosses any of the principal design sections and which meets the requirements of section 156.

159. — *Compressive stress in reinforcement.* — The following formulas shall be used in computing maximum compressive stress in the concrete in flat slabs; but the stress so computed shall not exceed 0.4 f'_c:

a) Compression due to negative moment, RM_0, in the two-column strips,

$$f_c = \frac{3.5\,RM_0}{kjb_1d^2}\left(1 - 1.2\,\frac{c}{l}\right) \quad \ldots \quad (41)$$

where b_1 is as specified in section 148.

b) Compression due to positive moment, RM_0, in the two-column strips, or negative or positive moment in the middle strip,

$$f_c = \frac{6\,RM_0}{kjl_1d^2} \quad \ldots\ldots \quad (42)$$

160. — *Shearing stress.* — See section 136.

161. — *Unusual panels.* — The moment coefficients, moment distribution, and slab thicknesses specified herein are for slabs which have three or more rows of panels in each direction, and in which the panels are approximately uniform in size. For structures having a width of one or two panels, and also for slabs having panels of markedly different sizes, an analysis shall be made of the moments developed in both slab and columns, and the values given herein modified accordingly. Slabs with paneled ceiling or with depressed paneling in the floor shall be considered as coming under the requirements herein given.

162. — *Bending moments in columns.* — See section 173.

G. — Reinforced concrete columns.

163. — *Limiting dimensions.* — The provisions in the following sections for the carrying capacity of reinforced columns are based on the assumption of a short column. Where the unsupported length is greater than 40 times the least radius of gyration (40R), the carrying capacity of the column shall be determined by formula 48 for slender columns. Principal columns in buildings shall have a width of not less than 12 inches. Posts that are not continuous from story to story shall have a width of not less than 6 inches.

164. — *Unsupported length.* — The unsupported length of a column in flat slab construction shall be taken as the clear distance between the under side of the capital and the top of the floor-slab below. For beam-and-slab construction the unsupported length of a column shall be taken as the clear distance between the under side of the shallowest beam framing into it and the top of the floor-slab below; where beams run in one direction only the clear distance between floor-slabs shall be used. For columns supported laterally by struts or beams only, two struts shall be considered an adequate support, provided the angle between the two planes formed by the axis of the column with the axis of each strut is not less than 75°, nor more than 105°. The unsupported length for this condition shall be considered the clear distance between struts. When haunches are used at the junction of beams or struts with columns, the clear distance between supports may be considered as reduced by two-thirds of the depth of the haunch.

165. — *Safe load on spiral columns.* — The symbols used in formulas 43 to 50 are defined in section 107, except as indicated in sections 165, 167, 170, 172, 180 and 188. The safe axial load on columns reinforced with longitudinal bars and closely spaced spirals enclosing a circular core shall be determined by the following formula :

$$P = A_c f_c + n f_c p A \ldots \quad (43)$$

where

- A = area of the concrete core enclosed within the spiral;
- P = total safe axial load on column whose $\frac{h}{R}$ is less than 40;
- p = ratio of effective area of longitudinal reinforcement to area of concrete core; and
- $A_c = A(1 - p)$ = net area of concrete core.

The allowable value of f_c for use in this type of column shall be determined by the following formula :

$$f_c = 300 + (0.10 + 4p) f'_c \ldots \quad (44)$$

The longitudinal reinforcement shall consist of at least six bars of minimum diameter of 1/2 inch, and its effective cross-sectional area shall not be less than 1 % nor more than 5 % of that of the enclosed core.

166. — *Spiral reinforcement.* — The spiral reinforcement shall be not less in amount than one-fourth the volume of the longitudinal reinforcement. It shall consist of evenly spaced continuous spirals held firmly in place and true to line by at least three vertical spacer bars. The spacing of the spirals shall not be greater than one-sixth of the diameter of the core and in no case more than 3 inches. The lateral reinforcement shall meet the requirements of the « Tentative specifications for cold-drawn steel wire for concrete reinforcement » (serial designation : A9—21) of the American Society for Testing Materials. Reinforcement shall be protected everywhere by a covering of concrete cast monolithic with the core, which shall have a minimum thickness of 1 1/2 inches in square columns and 2 inches in round or octagonal columns.

167. — *Safe load on columns with lateral ties.* — The safe axial load on columns reinforced with longitudinal bars and separate lateral ties shall be determined by the following formula :

$$P = A'_c f_c + A_s n f_c \ldots \quad (45)$$

where

- A'_c = net area of concrete in the column (total column area minus steel area); and
- A_s = effective cross-sectional area of longitudinal reinforcement.

The value of f_c for this type of column shall not exceed 0.20 f'_c. The amount of longitudinal reinforcement considered in the calculations shall not be more than 2 % nor less than 0.5 % of the total area of the column. The longitudinal reinforcement shall consist of not less than four bars of minimum diameter of 1/2 inch, placed with clear distance from the face of the column not less than 2 inches.

168. — *Lateral ties.* — Lateral ties shall be not less than 1/4 inch in diameter, spaced not farther than 8 inches apart.

169. — *Bending stress in columns.* — Reinforced concrete columns subjected to bending stresses shall be treated as follows :

a) *Spiral column.* — The compressive unit stress on the concrete within the core area under combined axial load and bending shall not exceed by more than 20 % the value given for axial load by formula 44.

b) *Columns with lateral ties.* — Addi-

tional longitudinal reinforcement not to exceed 2 % shall be used if required and the compressive unit stress on the concrete under combined axial load and bending may be increased to 0.30 f'_c.

Tension due to bending in the longitudinal reinforcement shall not exceed 16 000 lb. per square inch.

170. — *Composite columns.* — The safe carrying capacity of composite columns in which a structural steel or cast-iron column is thoroughly encased in a spirally reinforced concrete core shall be based on a certain unit stress for the steel or cast-iron core, plus a unit stress of 0.25 f'_c on the area within the spiral core. The unit compressive stress on the steel section shall be determined by the formula :

$$f_r = 18\,000 - 70 \frac{h}{R} \quad . \; . \; . \quad (46)$$

but shall not exceed 16 000 lb. per square inch. The unit stress on the cast-iron section shall be determined by the formula :

$$f_r = 12\,000 - 60 \frac{h}{R} \quad . \; . \; . \quad (47)$$

but shall not exceed 10 000 lb. per square inch. In formulas 46 and 47,

f_r = compressive unit stress in metal core; and
R = least radius of gyration of the steel or cast-iron section.

The diameter of the cast-iron section shall not exceed one-half of the diameter of the core within the spiral. The spiral reinforcement shall be not less than 0.5 % of the volume of the core within the spiral and shall conform in quality, spacing, and other requirements to the provisions for spirals in reinforced concrete columns. Ample sections of concrete and continuity of reinforcement shall be provided at the junction with beams or girders. The area of the concrete between the spiral and metal core shall be not less than that required to carry the total floor load of the story above on the basis of a stress in the concrete of 0.35 f'_c, unless special brackets are arranged on the metal core to receive directly the beam or slab loads.

171. — *Structural steel columns.* — The safe load on a structural steel column of a section which fully encloses or encases an area of concrete, and which is protected by an outside shell of concrete at least 3 inches thick, shall be computed in the same way as in the columns described in section 170, allowing 0.25 f'_c on the area of the concrete enclosed by the steel section. The outside shell shall be reinforced by wire mesh or hoops weighing not less than 0.2 lb. per square foot of surface of the core and with a maximum spacing of strands or hoops of 6 inches. Special brackets shall be used to receive the entire floor load at each story. The working stress in steel columns shall be calculated by formula 46, but shall not exceed 16 000 lb. per square inch.

172. — *Long columns.* — The permissible working unit stress on the core in axially loaded columns which have a length greater than 40 times the least radius of gyration of the column core (40R) shall be determined by the formula :

$$\frac{P'}{P} = 1.33 - \frac{h}{120\,R} \quad . \; . \; . \quad (48)$$

where

P′ = total safe axial load on long column;
P = total safe axial load on column of the same section whose $\frac{h}{R}$ is less than 40, determined as in section 167 : and
R = least radius of gyration of column core.

173. — *Bending moments in columns.* — The bending moments in interior and

exterior columns shall be determined on the basis of loading conditions and end restraint and shall be provided for in the design [1]. The recognized standard methods shall be followed in calculating the stresses due to combined axial load and bending.

H. — Footings.

174. — *Types.* — Various types of reinforced concrete footings are in use, depending on conditions. The fundamental principles of the design of reinforced concrete will generally apply to footings as to other structural members. The requirements for flexure and shear in sections 112 to 139, inclusive, shall govern the design of footings, except as hereinafter provided.

175. — *Distribution of pressure.* — The upward reaction per unit of area on the footing shall be taken as the column load divided by the area of base of the footing.

176. — *Pile footing.* — Footings carried on piles shall be treated in the same manner as those bearing directly on the soil, except that the reaction shall be considered as a series of concentrated loads applied at the pile centers.

177. — *Sloped footing.* — Footings in which the depth has been determined by the requirements for shear, as specified in section 137, may be sloped between the critical section and the edge of the footing, provided that the shear on no section outside the critical section exceeds the value specified, and provided, further, that the thickness of the footing above the reinforcement at the edge shall not be less than 6 inches for footings on soil, nor less than 12 inches for footings on piles.

[1] The Committee is not prepared to make more definite recommendations at this time.

178. — *Stepped footing.* — The top of the footing may be stepped instead of sloped, provided that the steps are so placed that the footing will have at all sections a depth at least as great as that required for a sloping top. Stepped footings shall be cast monolithically.

179. — *Critical section for bending.* — In a concrete footing which supports a concrete column or pedestal, the critical section for bending shall be taken at the face of the column or pedestal. Where steel or cast-iron bases are used the moment in the footing shall be calculated at the edge of the base and at the center. In calculating this moment, the column or pedestal load shall be assumed as uniformly distributed over its base.

180. — *Square column on square footing.* — For a square footing supporting a concentric square column, the bending moment at the critical section is that produced by the upward pressure on the trapezoid bounded by one face of the column, the corresponding outside edge of the footing, and the portions of the two diagonals. The center of application of the reaction on the two corner triangles of this trapezoid shall be taken at a distance from the face of the column equal to 0.6 of the projection of the footing. The center of the application of the reaction on the rectangular portion of the trapezoid shall be taken at its center of gravity. This gives a bending moment expressed by the formula :

$$M = \frac{w}{2}(a + 1.2\,c)\,c^2 \quad . \; . \; . \quad (49)$$

where

M = bending moment at critical section of footing;
a = the width of face of column or pedestal;
c = projection of the footing from face of colum; and
w = upward reaction per unit of area of base of footing.

181. — *Round column on square footing.* — Square footings supporting a round or octogonal column shall be treated in the same manner as for a square column, using for the distance a the side of a square having an area equal to the area enclosed within the perimeter of the column.

182. — *Reinforcement.* — The reinforcement necessary to resist the bending moment in each direction in the footing shall be determined as for a reinforced concrete beam; the effective depth of the footing shall be the depth from the top to the plane of the reinforcement. The required area of reinforcement thus calculated shall be spaced uniformly across the footing, unless the footing width is greater than the side of the column or pedestal plus twice the effective depth of the footing, in which case the width over which the reinforcement is spread may be increased to include one-half the remaining width of the footing. In order that no considerable area of the footing shall remain unreinforced, additional bars shall be placed outside of the width specified, but such bars shall not be considered as effective in resisting the calculated bending moment. For the extra bars a spacing double that used for the reinforcement within the effective belt may be used.

183. — *Concrete stress.* — The extreme fiber stress in compression in the concrete shall be kept within the limits specified in section 198. The extreme fiber stress in sloped or stepped footings shall be based on the exact shape of the section for a width not greater than that assumed effective for reinforcement.

184. — *Irregular footings.* — Rectangular or irregular-shaped footings shall be calculated by dividing the footings into rectangles or trapezoids tributary to the sides of the column, using the distance to the actual center of gravity of the area as the moment arm of the upward forces. Outstanding portions of combined footings shall be treated in the same manner. Other portions of combined footings shall be designed as beams or slabs.

185. — *Shearing stresses.* — See sections 137 to 139.

186. — *Bond stresses.* — See sections 142 to 144.

187. — *Transfer of stress from column reinforcement.* — The compressive stress in longitudinal reinforcement in columns or pedestals shall be transferred to the footing by one of the following methods :

a) By metal distributing bases having a sufficient area and thickness to transmit safely the load from the longitudinal reinforcement in compression and bending. The bases shall be accurately set and provided with a full bearing on the footing;

b) By dowels, at least one for each bar and of total sectional area not less than the area of the longitudinal column reinforcement. The dowels shall project into the columns or into the pedestal or footing a distance not less than 50 times the diameter of the column bars.

188. — *Pedestals without reinforcement.* — The allowable compressive unit stress on the gross area of a concentrically loaded pedestal without reinforcement shall not exceed 0.25 f'_c. If the column resting on such a pedestal is provided with distributing bases for the longitudinal reinforcement, the permissible compressive unit stress under the column core shall be determined by the following formula :

$$r_{\iota} = 0.25 f'_c \sqrt[3]{\frac{A}{A'}} \quad . \quad . \quad . \quad . \quad (50)$$

where

r_a = permissible working stress over the loaded area;

A = total net area of the top of pedestal; and

A' = loaded area of pedestal.

189. — *Pedestals with reinforcement.* — Where the permissible load at the top of a pedestal, determined by formula 50, is less than the column load to be supported, dowels shall be used as specified in section 187. If the height of the pedestal is not sufficient to give the required embedment to the dowels, they shall extend into the footing to a point 50 diameters below the top of the pedestal for plain bars and 40 diameters for deformed bars. If the column load divided by the cross-section of the pedestal exceeds 0.25 f'_c the pedestal shall be considered as a section of a column and spiral reinforcement shall be provided accordingly.

190. — *Permissible load at top of footings.* — Where distributing bases are used for transferring the stress from column reinforcement directly to the footing, the permissible compressive unit stress shall be determined by formula 50. This formula may be applied by using A as the area of the top horizontal surface of the footing or with the following modifications :

a) In footings, with sloping or stepped top in which a plane drawn from the edge of the base of the column so that it makes the greatest possible angle with the vertical, but remains entirely within the footing, has a slope with the horizontal not greater than 0.5, the total bearing area of the footing may be used for A;

b) In footings in which the slope of the plane referred to is greater than 0.5, but not greater than 2.0, the permissible compressive unit stress at the top shall be determined by direct proportion, in terms of the slope, between the value found for a slope of 0.5 and the value of 0.25 f'_c for a slope of 2.0. For a slope of 2.0 or greater the compressive unit stress at the top shall not exceed 0.25 f'_c.

191. — *Pedestal footings.* — Pedestal footings may be designed as pedestals, that is, without reinforcement other than that required to transmit the column load, except that when supported directly on driven piles, a mat of reinforcing bars consisting of not less than 0.20 square inch per foot of width in each direction shall be placed 3 inches above the top of the piles. The height of a pedestal footing shall not be greater than 4 times the average width.

I. — Reinforced concrete retaining walls.

192. — *Types.* — Reinforced concrete retaining walls may be of the following types :

a) Cantilever;
b) Counterforted;
c) Buttressed;
d) Cellular.

193. — *Loads and unit stresses.* — Reinforced concrete retaining walls shall be designed [1] for the loads and reactions, and shall be so proportioned that the permissible unit stresses specified in sections 196 to 208 are not exceeded. The heels of cantilever, counterforted, and buttressed retaining walls shall be proportioned for the maximum resultant vertical loads to which they will be subjected, but the sections shall be such that the normal permissible unit stresses will not be increased by more than 50 % when the reaction from the foundation bed is neglected.

---

[1] In proportioning retaining walls, consideration shall be given to the following :

a) Maximum bearing pressure of soil;

b) Uniformity of distribution of foundation pressure on yielding soils;

c) Stability against sliding;

d) Minor increase of the horizontal forces may seriously affect *a*) and *b*).

194. — *Details of design.* — The following principles shall be followed in the design of reinforced concrete retaining walls :

a) The unsupported toe and heel of the base slabs shall be considered as cantilever beams fixed at the edge of the support;

b) The vertical section of a cantilever wall shall be considered as a cantilever beam fixed at the top of the base;

c) The vertical sections of counterforted and buttressed walls and parts of base slabs supported by the counterforts or buttresses shall be designed in accordance with the requirements specified herein for the continuous slab;

d) The exposed faces of walls without buttresses shall preferably be given a batter of not less than 1/4 inch in 12 inches;

e) Counterforts shall be designed in accordance with the requirements specified for T-beams. Stirrups shall be provided in the counterforts to take the reaction from these spans when the tension reinforcement of the face walls and heels of bases is designed to span between the counterforts. Stirrups shall be anchored as near the exposed faces of the face walls, and as near the lower face of the bases, as practicable;

f) Buttresses shall be designed in accordance with the requirements specified for rectangular beams;

g) The shearing stress at the junction of the base with counterforts or buttresses shall not exceed the values specified in sections 120 to 135;

h) Horizontal metal reinforcement shall be well distributed of such form as to develop a high bond resistance. At least 0.25 square inch of horizontal metal reinforcement for each foot of height shall be provided near exposed surfaces not otherwise reinforced, to resist the formation of temperature and shrinkage cracks;

i) Provision for temperature changes shall be made by grooved lock-joints spaced not over 60 foot apart;

j) Counterforts and buttresses, where used, shall be located under all points of concentrated loading, and at intermediate points spaced 8 to 12 feet apart;

k) The walls shall be cast monolithically between expansion joints, unless construction joints made in accordance with sections 69 and 73 are provided.

195. — *Drains.* — Drains or « weep holes » not less than 4 inches in diameter and not more than 10 feet apart, shall be provided. In counterforted walls there shall be at least one drain for each pocket formed by the counterforts.

J. — Floor-slabs supported on four sides (1).

K. — Shrinkage and temperature stresses (1).

L. — Summary of working stresses.

196. — *Notation :*

f'_c = ultimate compressive strength of concrete at age of 28 days, based on tests of 6 by 12-inches, or 8 by 16-inches, cylinders, made and tested in accordance with the « Standard methods of making and storing specimens of concrete in the field » and the « Tentative methods of making compression tests of concrete ».

a) MAXIMUM DIRECT STRESSES IN CONCRETE.

197. — *Direct compression :*

a) Columns whose length does not exceed 40 R :

1° With spirals : varies with amount of longitudinal reinforcement.

2° Without spirals.............. 0.20 f'_c.

b) 3° Long columns (see section 172).

c) Piers and pedestals :

1° Without reinforcement.... 0.25 f'_c.

2° For special cases (see section 188).

(1) The Committee is not now ready to report on these subjects.

198. — *Compression in extreme fiber :*

a) Extreme fiber stress in flexure. . . . . $0.40 f'_c$.

b) Extreme fiber stress adjacent to supports of continuous beams.... $0.45 f'_c$.

199. — *Bearing compression.* — Anchorage of reinforcement............ $0.50 f'_c$.

200. — *Tension.* — All concrete members : None.

b) MAXIMUM SHEARING STRESSES IN CONCRETE

201. — *Beams without web reinforcement :*

a) Longitudinal bars anchored... $0.03 f'_c$.

b) Longitudinal bars not anchored.............. .... $0.02 f'_c$.

202. — *Beams with reinforcement :*

a) Beams with stirrups (see sections 125 and 128).

b) Beams with bars bent up in several planes (see section 125).

c) Beams with bars bent up in a single plane :

1° Longitudinal bars anchored.................... $0.12 f'_c$.

2° Longitudinal bars not anchored................ $0.06 f'_c$.

203. — *Flat slabs :*

a) Shear at distance, *d*, from capital or dropped panel.................. $0.03 f'_c$.

b) Other limiting cases in flat slabs (see section 136).

204. — *Footings :*

a) Longitudinal bars anchored... $0.03 f'_c$.

b) Longitudinal bars not anchored........................ $0.02 f'_c$.

c) MAXIMUM STRESSES IN REINFORCEMENT.

205. — *Tension in steel :*

	Lb. per sq. in.
a) Billet-steel bars :	
1° Structural steel grade.. . ..	16 000
2° Intermediate grade	18 000
3° Hard grade........	18 000
b) Rail-steel bars.....................	16 000
c) Structural steel......................	16 000

d) Cold-drawn steel wire :

1° Spirals....... stress not calculated.

2° Elsewhere.. 18 000 lb. per sq. in.

206. — *Compression in steel :*

a) Bars.... same as section 205 a) and b).

b) Structural steel core of composite column : 18 000 lb. per square inch, reduced for slenderness ratio.

c) Structural steel column : 16 000 lb. per square inch, reduced for slenderness ratio.

207. — *Compression in cast iron :*

Composite columns with spiral. .... 10 000 lb. per square inch.

d) MAXIMUM BOND BETWEEN CONCRETE AND STEEL.

208. — *Bond :*

a) Beams and slabs, plain bars... $0.04 f'_c$.

b) Beams and slabs, deformed bars .... $0.05 f'_c$.

c) Footings, plain bars, one-way............................... $0.04 f'_c$.

d) Footings, deformed bars, one-way. .... $0.05 f'_c$.

e) Footings, two-way reinforcement... c) or d) reduced by 25 %.

f) Footings, each additional direction of reinforcement............ c) or d) reduced by 10 %.

APPENDIX

STANDARD NOTATION.

All symbols used in the « Tentative specifications for concrete and reinforced concrete » have been collected here for convenience of reference. The symbols are in general defined in the text near the point where formulas occur. In a few instances the same symbol is used in two distinct senses; however, there is little danger of confusion from this source.

a = spacing of web reinforcement bars measured perpendicular to their direction (see section 135);

a = width of face of column or pedestal;

α = angle between inclined web bars and longitudinal bars;

A = total net area of column, footing, or pedestal, exclusive of fire-proofing;

A' = loaded area of pedestal, pier or footing

A_c = $A(1-p)$ = net area of concrete core of column;

A'_c = net area of concrete in columns (total column area minus steel area);

A_s = effective cross-sectional area of metal reinforcement in tension in beams or compression in columns; and the effective cross-sectional area of metal reinforcement which crosses any of the principal design sections of a flat slab and which meets the requirements of section 156;

A_v = total area of web reinforcement in tension within a distance of a (a_1, a_2, a_3, etc.) or the total area of all bars bent up in any one plane;

b = width of rectangular beam or width of flange of T-beam;

b' = width of stem of T-beam;

b_1 = dimension of the dropped panel of a flat slab in the direction parallel to l_1;

c = base diameter of the largest right circular cone which lies entirely within the column (including the capital) whose vertex angle is 90° and whose base is 1 1/2 inches below the bottom of the slab or the bottom of the dropped panel;

c = projection of footing from face of column;

C = total compressive stress in concrete;

C = total compressive stress in reinforcement;

d = depth from compression surface of beam or slab to center of longitudinal tension reinforcement;

d' = depth from compression surface of beam or slab to center of compression reinforcement;

E_c = modulus of elasticity of concrete in compression;

E_s = modulus of elasticity of steel in tension = 30 000 000 lb. per square inch;

f_c = compressive unit stress in extreme fiber of concrete;

f'_c = ultimate compressive strength of concrete at age of 28 days, based on tests of 6 by 12-inches or 8 by 16-inches cylinders made and tested in accordance with the Standard methods of making and storing specimens of concrete in the field and the Tentative methods of making compression tests of concrete;

f_r = compressive unit stress in metal core;

f_s = tensile unit stress in longitudinal reinforcement;

f'_s = compressive unit stress in longitudina reinforcement;

f_v = tensile unit stress in web reinforcement;

h = unsupported length of column;

I = moment of inertia of a section about the neutral axis for bending;

j = ratio of lever arm of resisting couple to depth, d;

jd = $d - z$ = arm of resisting couple;

k = ratio of depth of neutral axis to depth, d;

l = span length of beam or slab (general distance from center to center of supports; for special cases, see sections 108 and 148);

l = span length of flat slab, center to center of columns, in the rectangular direction in which moments are considered;

l_1 = span length of flat slab, center to center of columns, perpendicular to the rectan-

gular direction in which moments are considered;

M = bending moment or moment of resistance in general;

M_o = sum of positive and negative bending moments in either rectangular direction, at the principal design sections of a panel of a flat slab;

$n = \frac{E_s}{E_c}$ = ratio of modulus of elasticity of steel to that of concrete;

o = perimeter of bar;

Σo = sum of perimeters of bars in one set;

p = ratio of effective area of tension reinforcement to effective area of concrete in beams $= \frac{A_s}{bd}$; and the ratio of effective area of longitudinal reinforcement to the area of the concrete core in columns;

p' = ratio of effective area of compression reinforcement to effective area of concrete in beams;

P = total safe axial load on columns whose $\frac{h}{R}$ is less than 40;

P' = total safe axial load on long column;

r = ratio of cross-sectional area of negative reinforcement which crosses entirely over the column capital of a flat slab or over the dropped panel, to the total cross-sectional area of the negative reinforcement in the two-column strips;

r_a = permissible working stress in concrete over the loaded area of a pedestal, pier or footing;

R = ratio of positive or negative moment in two-column strips or one middle strip of a flat slab, to M_o;

R = least radius of gyration of a section;

s = spacing of web members, measured at the neutral axis and in the direction of the longitudinal axis of the beam;

t = thickness of flange of T-beam;

t_1 = thickness of flat slab without dropped panels or thickness of a dropped panel;

t_2 = thickness of flat slab with dropped panels at points away from the dropped panel;

T = total tensile stress in longitudinal reinforcement;

u = bond stress per unit of area of surface of bar;

v = shearing unit stress;

V = total shear;

V' = external shear on any section after deducting that carried by the concrete;

w = uniformly distributed load per unit of length of beam or slab;

w = upward reaction per unit of area of base of footing;

w' = uniformly distributed dead and live load per unit of area of a floor or roof;

W = total dead and live load uniformly distributed over a single panel area;

z = depth from compression surface of beam or slab to resultant of compressive stresses.

These tentative specifications are completed with a table giving the proportions in which Portland cement and a wide range in sizes of fine and coarse aggregates should be mixed to obtain concrete of compressive strengths ranging from 1 500 to 3 000 lb. per square inch at twenty-eight days.

Proportions are given for concrete of four different consistencies.

The purpose of the table is twofold :

1° To furnish a guide in the selection of mixtures to be used in preliminary investigations of the strength of concrete from givèn materials;

2° To indicate proportions which may be expected to produce concrete of a given strength under average conditions where control tests are not made.

We will given in a following note an account of the American « Slump test » determining the consistency of concrete and of the discussion on these tentative specifications before the American Society of Civil Engineers.

(*To follow.*) R. D.

Description of "slump test" as applied to concrete and reinforced concrete.

We give hereafter an account of the proposed test for consistency of Portland cement concrete known in American practice as the *Slump test.*

The test specimen shall be formed in a galvanised iron mould in the form of a truncated cone 12 inches high having a lower diameter of 8 inches and an upper diameter of 4 inches. The base and the top shall be open and parallel to each other and at right angles to the axis of the cone. The mould shall be provided with foot pieces and handles.

When the test is made at the mixer, the sample shall be taken from the pile of concrete immediately after the entire batch has been discharged. When testing concrete that has been conveyed from a central mixing plant, the sample shall be taken from the concrete immediately after it has been dumped on the site.

The mould shall be placed on a flat non-absorbent surface, such as a smooth plank or a slab of concrete, and the operator shall hold the form firmly in place, while it is being filled, by standing on the foot pieces. The mould shall be filled to about one fourth of its height with the concrete which shall then be puddled, using 20 to 30 strokes of a 1/2 inch rod pointed at the lower end. The filling shall be completed in successive layers similar to the first and the top struck off so that the mould is completely filled. The mould shall be allowed to stand for exactly three minutes and shall then be raised vertically from the concrete. The moulded concrete shall then be allowed to settle down until it assumes its final position and the resultant height of the specimen measured.

The original height of 12 inches less the final height after subsidence is called in American practice the « Slump ».

R. D.

[624. (01 (.43)]

New German rules for railway bridge calculations.

The following is an extract from the *Zentralblatt der Bauverwaltung*, Nos. 51 and 53 for 1922, giving a synopsis of the most important specifications, according to the new German rules for 1922, for calculations in connection with metal railway bridges.

Method of calculation. — It is recommended that the calculations for the different parts should not be too close in order to give a certain margin in the event of an increase in loading over that which is anticipated at the present time.

Stringers, cross girders and their joints should be as rigid as possible.

Stringers should be calculated as supported only when they are simply attached by two angle brackets to the cross girders.

The reaction at the support should be increased by 20 % in calculating the rivetting.

When the stringers are fixed to the cross girders so as to make a sufficiently rigid connection, one may take the moment at the point of fixing as having a value of 3/4, and the moment at the centre as being 4/5 of the maximum moment to which the stringer is subjected, if considered as supported at two points.

The cross girders are assumed to be supported at the centres of the main girders.

The reaction at the support should be increased by 20 % in calculating the attachment rivetting.

The flange plates are to be extended beyond their theoretical length, sufficiently to allow for the number of rivets required to develop the tension in them.

In the calculations of the main girders, the metal taken out by two rivet holes at least should be deducted in the flanges and 15 % of the metal in the web, to allow for vertical rows of rivets.

In the case of beams embedded in the concrete, account will only be taken of the metal, the effect of the surrounding concrete being neglected.

Bolt holes in the webs of secondary beams may be neglected.

In calculating loads, it may be assumed that the weight on a single line of track is to be spread out over a width of 3 m. 50 (11 ft. 6 in.).

In the primary calculations, the forces to be dealt with are those due to dead load, live load, centrifugal force and temperature effects.

The effects of wind, of braking or tractive force, lateral oscillation, and friction of bearings due to expansion or variation in the level of the supports to be considered in the secondary calculations.

For spans less than 40 m. (131 feet), it will be sufficient as a rule to deal only with the primary effects; the secondary ones need not be considered except where the total stress in important members exceeds the stress laid down in the specification.

One may in the ordinary way neglect calculations of the secondary effects, provided that the various elements of the lattice work or of the plate work are of sufficient strength.

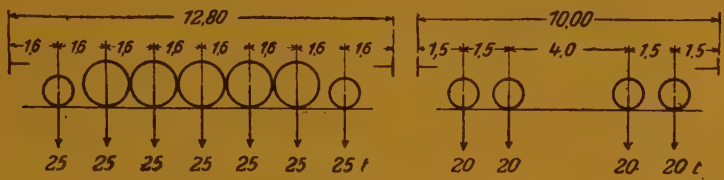
When these secondary effects are included, the maximum stress allowable in the metal may however be increased.

In calculations for bridges carrying two lines of track, it is assumed that both lines will be loaded simultaneously (that is if this produces the most severe conditions).

Loading :

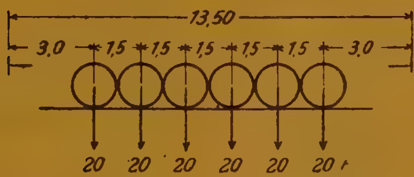
1° *Dead load.* — The dead load assumed in the preliminary calculations should be checked when the design is completed. In cases where the stresses resulting from the load as checked exceed the admissible stress by 3 %, fresh calculations must be made.

2° *Live load.* — The system of loading is represented by trains N, E and G below.



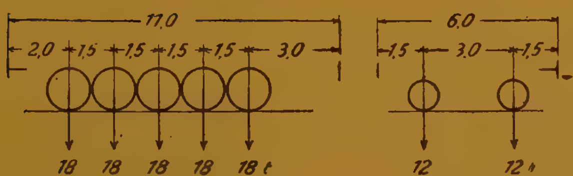
b

Train N.



c

Train E.



d e

Train G.

In calculations for the abutments, the load due to the train is to be taken as equivalent to an additional height of filling equal to 2 m. 20 (7 ft. 2 5/8 in.) for train N, 1 m. 40 (4 ft. 7 1/8 in.) for train E, and 1 m. 30 (4 ft. 3 3/16 in.) for train G.

The specific gravity of earth is 1 t. 8 per cubic metre (1.35 English tons per cubic yard), and the load for a single line of track is taken as being distributed over a width of 3 m. 50 (11 ft. 6 in.).

The service footways should be calculated as having a uniformly distributed load of 400 kgr. per square metre (82 lb. per square foot). The pressure on the hand rail is taken as 50 kgr. per lineal metre (101 lb. per yard).

For ordinary passenger foot-bridges the load is 500 kgr. per square metre (102 lb. per square foot) and the pressure on the hand rail 100 kgr. per lineal metre (202 lb. per yard).

In calculations for platforms, provision must be made for a concentrated load of 1 t., and a dead load of 500 kgr. per square metre (102 lb. per square foot)

within a rectangle of 1 × 2 m. (3 ft. 3 3/8 in. × 6 ft. 6 3/4 in.), which is the space covered by a 1 t. truck.

Centrifugal force. — Centrifugal force is supposed to act at the centre of gravity of the vehicles, which is taken as 2 m. (6 ft. 6 3/4 in.) above rail level. Its value is :

$$H_f = P \frac{v^2}{127 \cdot r}$$

v, equals speed in kilometres per hour.
r, is radius in metres.

Temperature effects. — The range of temperature to be allowed for is from 25° C. below zero to 45° C. above zero (from — 13° F. to + 113° F.), thus if erected at 10° C. (50° F.), the range of temperature variation would be 35° C. (63° F.) above and below this temperature. In case of unequal heating or cooling of one part of the structure, the temperature difference is assumed to be 15° C. (27° F.).

Secondary effects. — The force of the wind is calculated as 150 kgr. per square metre (31 lb. per square foot) for the bridge when loaded, and 250 kgr. per square metre (51 lb. per square foot) when unloaded.

The longitudinal effects of braking and tractive force of locomotives. — These forces, which act at rail level, are in the direction in which the train is running in the case of braking, and in the opposite direction in the case of tractive force.

The force due to braking is assumed to be 1/7 of the weight on the wheels of the locomotive and tender, and 1/2 the weight of the other vehicles which are on the bridge.

Adhesion is taken as 1/7 of the total weight on the wheels of the locomotive.

Effects of lateral oscillation. — The forces due to lateral oscillation which enter into calculation for the wind bracing, is taken as being a moving horizontal force normal to the track with an intensity equal to 1/5 of the vertical weight on the most heavily loaded pair of wheels.

In the case of bridges on a curve, it is not necessary to add the effects of centrifugal force and lateral oscillation, but whichever of these forces is the most severe is to be taken.

Horizontal reactions at the abutments.— In the case of sliding bearings, the reaction due to friction is taken as being 0.2 of the vertical reaction, while on roller bearings this reaction is 0.03 of the vertical reaction.

Permissible stresses. — The German specification introduces for the first time a *coefficient for dynamic augment,* which is termed *Stosszahl* and which the Americans and English call *impact.* This coefficient φ is applied to axial loads, bending moments and shearing forces, etc., calculated by the ordinary methods.

It depends essentially on the span of the bridge and on the method in which the track is carried on the bridge.

$\varphi = 1.2 + \dfrac{17}{L + 28}$ for a track resting directly on the bridge-work within the interposition of sleepers.

$\varphi = 1.19 + \dfrac{21}{L + 46}$ for a track carried on sleepers resting on the bridge-work.

$\varphi = 1.11 + \dfrac{56}{L + 144}$ for a ballasted track.

The three values of the coefficient are thus 1.8 — 1.65 — 1.5 for an infinitely short span, and 1.42 — 1.41 and 1.40 for a span of 50 m. (164 feet).

For a span of 140 m. (459 feet), $\varphi = 1.3$ (under the second condition) and remains at this value for larger spans.

In calculating the members of a bridge, the spans to be assumed are the distances between the axes of their supports (stringers or cross girders).

In the case of continuous girders the span is to be taken as the distance between the supports. In jointed « cantilever » beams the span to be taken is that between the axes of the joints.

Maximum permissible tensile stress whether axial or bending.

METAL.	Elastic limit in kilogrammes per square centimetre (in lb. per square inch).	Stresses of the first order, in kilogrammes par square centimetre (in lb. per square inch).	Stresses of the second order, in kilogrammes per square centimetre (in lb. per square inch).
		New bridges :	
Mild steel	2 400 (34 000)	1 400 (19 900)	1 600 (22 700)
High tensile steel. .	3 800 (54 000)	$1\,400 \times \frac{3\,800}{2\,400} = 2\,200$ (31 300)	$1\,600 \times \frac{3\,800}{2\,400} = 2\,500$ (35 800)
		Existing bridges :	
Wrought iron and mild steel prior to 1895	2 200 (31 300)	1 400 (19 900)	1 600 (22 700)
Mild steel after 1895.	2 400 (34 000)	1 500 (21 300)	1 700 (24 200)
Permissible shearing stress 0.8 of the above stresses.			

These stresses are higher than those which have been previously allowed.

In footbridges the maximum permissible stress in tension and bending is 1 400 kgr. per square centimetre (19 900 lb. per square inch) and the shearing stress 0.8 of this stress.

Calculation of struts. — For the calculation of struts, the new German rule fixes on the one hand the limiting value of the crippling force which may be allowed with reference to the ratio which the length bears to the radius of gyration, and on the other hand, applies a coefficent ω to axial forces acting on the struts.

If λ is the ratio of length of the least radius of gyration and σ_k the maximum crippling load, σ_k has the following values for mild steel :

$\lambda \leqslant 60$, $\sigma_k = 2\,400$ kgr. per cm².

$\lambda > 60$ and $\leqslant 100$, $\sigma_k = 2\,817 - 6.95\,\lambda$.

$\lambda \geqslant 100$, $\sigma_k = \dfrac{21\,220\,000}{\lambda^2}$ in kgr. per cm².

The factors of safety used are 2 and 4 for $\lambda \leqslant 60$ and $\lambda \geqslant 100$, under the effects of the principal load.

Between $\lambda = 0$ and $\lambda = 100$. the factor of safety follows a straight line law and may be determined by interpolation.

The coefficient ω has the following values for $\lambda \leqslant 60$:

Wrought iron and old mild steel :

$$\omega = \frac{1\,400}{2\,200} \cdot 2 = 1.27$$

New bridges in mild steel :

$$\omega = \frac{1\,400}{2\,400} \cdot 2 = 1.17$$

High tension steel :

$$\omega = \frac{2\,200}{3\,800} \cdot 2 = 1.17$$

The following table gives the various values of ω :

$\lambda = 0$ to 60	70	80	90	100	110	120	130	140	150
$\sigma_k = 2\,400$	2 330	2 261	2 191	2 122	1 754	1 474	1 256	1 083	943
$\omega = 1.17$	1.5	1.86	2.24	2.64	3.19	3.8	4.46	5.17	5.94

In the case of an axial pull, the tension in the bar should be multiplied by ω and the bar treated as an ordinary bar, the section of rivets not being deducted.

In the case of an eccentric loading, the additionnal tension due to bending must also be taken into account.

In built up sections the ratio λ of the elements must not exceed λ for the whole built up section and must not exceed 30.

The length as regards buckling is taken as between the end attachment brackets or between the joints of the lattice work.

In lattice work main girders the length of the booms as regards buckling is the length between panel points.

For the uprights, the length as regards buckling perpendicular to the girder is the arithmetic mean between the total height, booms included, and the free height between the jointing brackets.

Bridges without lateral bracing. — These bridges should be checked by being considered as subjected to horizontal forces normal to the axis of the bridge. Two successive panels (uprights and stays) should be examined as follows :

First panel. — Assume it to be subjected to the live load and that the normal force is exerted from the exterior towards the interior by equal and opposite forces = 1/100 of the maximum tension in the adjacent boom including the dynamic augment.

Second panel. — Suppose unloaded and acted upon in the direction from the interior towards the exterior by two equal and opposite forces = 1/200 of the tension in the boom.

The sum of the resultant deflections in the two uprights should be less than 1/200 of the span of the panels.

Permissible working stresses in the wind bracing.

The stresses vary in accordance with the span as follows :

Span, in metres (in feet)	10 (33)	20 (66)	40 (131)	60 (197)	80 (262)	100 (330)	120 (394)	140 (460)
Working stress, in kilogrammes per square centimetre (in lb. per square inch)	970 (13 800)	1 030 (14 650)	1 100 (15 650)	1 150 (16 360)	1 180 (16 780)	1 200 (17 000)	1 210 (17 210)	1 230 (17 490)

Rivets. — The maximum shear stress of rivets is taken as 0.8 of the permissible stress for bending and tension.

The maximum working stress for the compression of the shank is twice the latter.

Supports. — The permissible working stresses in kilogrammes per square centimetre are as follows :

—	Principal forces.		Total forces.	
	Bending.	Compression.	Bending.	Compression.
Cast steel, in kilogrammes per square centimetre (in lb. per square inch).	1 200 (17 000)	1 500 (21 300)	1 300 (18 500)	1 600 (22 700)
Wrought steel, in kilogrammes per square centimetre (in lb. per square inch)	1 400 (19 900)	1 700 (24 200)	1 500 (21 300)	1 900 (27 000)

For bearing surfaces which are in contact along a line or at a point, the following maximum stresses in kilogrammes per square centimetre (in lb. per square inch) are allowed :

Cast steel	6 500 (92 440)
Wrought steel. . . .	7 500 (106 670)

If there are two moving rollers, these amounts should be diminished by 1 000 kgr. (14 220 lb) in order to allow for an unequal distribution of the forces.

For masonry work carrying bearing plates, the following pressure expressed in kilogrammes per square centimetre are allowed in accordance with the span of the bridge.

Span, in metres (in feet) . . .	10 (33)	20 (66)	40 (131)	60 (197)	80 (262)	100 (330)	120 (394)	140 (460)	150 (492)
Pressure between bearing plate and supporting masonry, in kilogrammes per square centimetre (in lb. per square inch).	20 (284)	22 (313)	26 (370)	30 (427)	34 (484)	38 (540)	42 (597)	46 (654)	48 (683)
Pressure between supporting masonry and foundations of squared stonework in cement, in kilogrammes per square centimetre (in lb. per square inch).	10 (142)	12 (171)	16 (228)	20 (284)	24 (341)	28 (398)	32 (455)	36 (512)	38 (540)
Pressure between supporting masonry and foundations of rubble set in cement, in kilogrammes per square centimetre (in lb. per square inch).	6 (85)	7 (100)	9 (128)	11 (156)	13 (185)	15 (213)	17 (242)	19 (270)	20 (284)
Maximum tension in the supporting stonework due to sliding and bending, in kilogrammes per square centimetre (in lb. per square inch)	6 (85)	7 (100)	9 (128)	11 (156)	13 (185)	15 (213)	17 (242)	19 (270)	20 (284)

In the case of eccentric loading, the maximum tension may be increased by 20 %, not taking dynamic effect into account.

Permissible deflection. — The deflection must not exceed 1/1 000 of the span under the live load. The coefficient for bridges having built in stringers is 1/800.

Permissible stresses for timber. — For resinous timber the maximum tension due to bending is 90 kgr. per square centimetre (1 280 lb. per square inch). Tension at right angles to the fibres must not exceed 15 kgr., per square centimetre (213 lb. per square inch).

For oak and beech, these tensions are 110 and 30 kgr. per square centimetre (1 565 and 427 lb. per square inch) respectively.

In the case of timber, the live load will be calculated without dynamic augment (1).

R. D.

(1) *N. B.* — The new German regulations from which this information is taken is published under the title : *Deutsche Reichsbahn (Vorschriften für Eisenbauwerke) Grundlagen für das Entwerfen und Berechnen eiserner Eisenbahnbrücken.* Amtliche Ausgabe, Berlin 1922, W. Ernst und Sohn.

[625 .144.4]

Mechanical track construction and maintenance, (1)

By Nugent M. CLOUGHER, A. C. G. I., A. M. Inst. T., F. R. G. S. (Fellow).

Figs. 1 to 14, pp. 926 to 940.

(*Journal and Report of Proceedings of the Permanent-Way Institution.*)

Introduction.

If it is permitted to prophesy, the outstanding feature of our present age will be the development of the use of Mechanical Appliances for Permanent Way work. Our ideas and general outlook have changed greatly during the last few years, and there is every reason to believe that the changes which are taking place will ultimately lead to better things not only for our own Nation and ourselves, but also for the science of Railway Construction and Maintenance, which we have so much at heart.

We must allow our heads to do a large part of the work of our muscles. It is possible to take a too advanced view of what may be accomplished by mechanical aids to work, yet we can feel assured that during the next few years such machines as will help in everyday track work will more and more become integral parts of the equipment of Railways, for all are finding it essential to demand the highest quality of work that can be produced both from the standpoint of maintenance costs and for public safety, and this they humanly desire at as reasonable a figure as is possible.

Thus it is that we cannot afford to neglect anything that will tend to raise the standard of work and efficiency of the individual worker.

As the traffic requirements become more stringent, even greater demands are placed upon roadbed and track, and this again leads to the direction of new methods to augment those already existing. During the early days in the study of modern track development, it was decided that little advancement could be made until more was known of what actually took place along a line as regards strains and stresses, and what were the powers of resistance offered by various kinds of track material.

Upwards of 35 years ago that eminent French Permanent Way Engineer, M. Albert Collet, commenced to investigate these problems and as a result of his study, many steps have become possible. A very important question was that of rail and chair fastenings, and the Extrahometre was introduced as affording a means for carrying out the necessary tests. This instrument indicates on a dial the maximum hold that various types of fastenings have on a sleeper. The Torsiometre indicates the resistance to turning of coach screws, nuts on throughbolts and fangbolts, etc. The instrument records up to 450 lb., which is higher than is ever attained in practice. The Declimetre is used to show the resistance to side pull and overturning of various fastenings. It registers up to 4 tons. A further instrument is used by placing it

(1) Paper read before the London section, 13 January 1922.

between the two rails when pressure is exerted to test the resistance given to overturning of rails and fastenings and spreading of the track. The dial indicates up to 25 tons. The BOURRAMETRE was designed to study various methods of packing sleepers by the crushing force required for a prism of ballast of standard size.

After much study the conclusion was arrived at that electricity was the most suitable and most easily adapted power for use in connection with mechanical trackwork. The electricity for the various machines that will later be described is generated either by a small petrol electric generating set that moves along the line with the machines and is easily removed from the track, or else by a large generating set which is operated with petrol, paraffin, or steam, and which generating set will give sufficient current to work the various machines at the same time. In this latter case movable trolley wires are extended out along the line, the power being generated at some point about half way along the length of the wires and just off the track. By a special and ingenious device the *large* generator may be moved off the rails and put into position beside the line in 5 minutes. It is also supplied with road wheels for use when necessary. A sufficient length of trolley wire is provided so that the large generator needs only be moved every day or so.

A practice that is becoming very popular at the present time is that of using the small generator off the track in a similar method to the large generator, using likewise the trolley wires from which the individual machines are fed. This is found to be of considerable assistance when clearing the track of machines for the passage of trains. It is perhaps desirable here to point out that all machines referred to for use along the line with the exception of the large generating set, may be removed from the track in about one minute.

The results achieved, and which will shortly be explained, are the outcome of many years of study, and it is interesting to note that the machines proved of very considerable assistance to both the British and French Armies in France for the Military Railways during the late war.

When it is said that the results have required years of study, this has not solely been theoretical, but has been carried out under actual practice : this will be seen from the fact that up to the end of 1918 the Mechanical System had been used on 3 280 miles of line and 2 350 000 sleepers had been worked on independently. Between July 1920 and August 1921, more than a quarter of a million sleepers were dealt with for one British Railway alone. Up to comparatively recently very little work was done outside France, as so much was being accomplished in that country. From 1 January 1914 to the outbreak of war, being 7 months, 23 sets of machines were working simultaneously, in France on the Paris-Lyons-Mediterranean, State, Metropolitan, Eastern and Paris-Orleans Railways, besides the work in Spain, Italy, Algerian and Asia Minor.

As perhaps anticipating some questions it is notable that the system has been used in the building of lines under the French Government in the French Zone in Morocco, where native labour was employed. A very interesting article by M. Cartault, honorary chief engineer of the Paris-Lyons-Mediterranean Railway, has appeared in the May issue (1921) of the *Bulletin of the International Railway Association*. In this article he points out that up to the 1 January 1921, this system of Mechanical Railway Construction and Maintenance had been used on just under 2 000 miles of line on the Paris - Lyons - Mediterranean Railway of France alone.

M. Collet's apparatus was inspected by the Members of the Permanent-Way Institution during the Paris Convention in

1914, and was discussed and illustrated in the *Journal* for August 1914.

Relaying.

The chief aims of the Methodical Mechanical Renewing are, first, to relay the track very quickly, and second, to have only a very short space of line between the untouched track and that which is completely finished, ready for the resumption of the normal traffic at normal speeds. This space is generally only a few rails lengths.

Before the track is touched the new rails and sleepers are distributed along the line, the ballast is then removed from around the sleepers and with the aid of the screwing and boring machines a section of the track is soon taken up and replaced by the new material when immediately the packing machines follow on to complete the operation.

It is with the assistance of the various electrically operated machines that it is possible to carry out the work rapidly, and completely, so as to interfere as little as possible with the traffic of the line.

Mechanical methodical track revision.

A system that is being adopted more and more and is perhaps worthy of some notice is Mechanical Methodical Revision. This is carried out on main and secondary lines from every two to five years, according to their importance. The system consists in removing the ballast from around the ends of the sleepers to about 8 inches inside the rails, to see if the sleeper is in a condition to require renewing. Immediately after this operation, a screwing machine is moved along the line and this tests each screw-head to ascertain that the screw is holding. If, however, it rotates in the hole, the machine is reversed and the screw, together with the other screws in the sleeper, is removed. The sleeper is then changed, or else the holes are plugged and after the position of the chairs on the sleeper has been altered slightly, new holes are bored with the boring machine which follows immediately after, and next the screws are put down in the new holes by the second screwing machine which follows the boring machine. The work is quickly carried out, and it is possible to go over a line thoroughly in this manner in a short time, being assured that the track is left in a sound condition.

Packing.

No apology is needed for dealing with the subject of packing before discussing other branches of work which, in the normal course of events, should come first.

Both from the standpoint of securing a satisfactory road-bed and from that of financial considerations, packing is constantly before our notice. The importance of the matter is referred to in text-books by authorities, though it is remarkable how little has been written on the subject. I will make but two quotations.

One engineer points out that

« The proper tamping of ties is perhaps the most important of all track work. »

while another writes

« It is not sufficiently well understood that the accuracy and permanence of surface, as well as the general efficiency and economy of maintenance-of-way, depend to a very large degree upon the proper tamping of the track. »

Many consider that packing can readily be carried out by anyone supplied with the requisite beater or packing bar, but experience soon shows that this is not the case. Once more to call in outside evidence to augment our own experience we find the situation well expressed in the following extracts :

« It requires experience and judgment

to shovel tamp ballast under a series of ties so as to maintain track in proper surface, for not only must the ends of the tie have equally compact beds, but all the ties must be equally bedded. »

and again

« As no two men tamp a tie alike, the same man should tamp the heads and ends of all ties at one joint. »

A great advantage would therefore become apparent from the introducing of some system of packing that would render it uniform along the line as from one sleeper to another, and would at the same time cause packing as carried out by different men to give some standard result. In all this we are looking at the possibilities of obtaining uniformity even if only retaining in general the same standard that exists on our lines at the present time, and without looking into the chances of materially raising such standard.

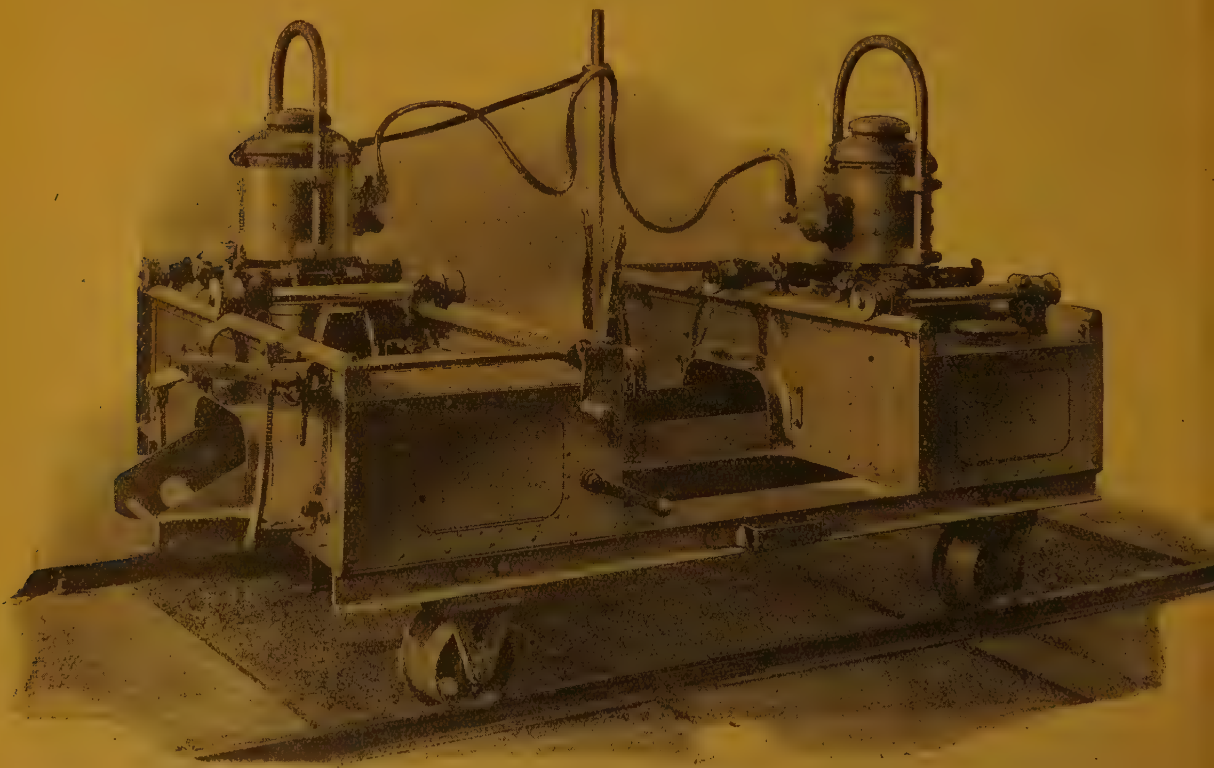


Fig. 1. — Adzing machine.

Happily, perfection in packing has not yet been attained, and there is plenty of scope for investigation with the idea of rendering the results more capable of carrying the varying conditions of traffic that we find existing to day.

It will, no doubt, be generally agreed that the road-bed ultimately obtained in this country is of a very high standard, but there is a considerable and undesirable loss of both time and money due to the period that must elapse before a

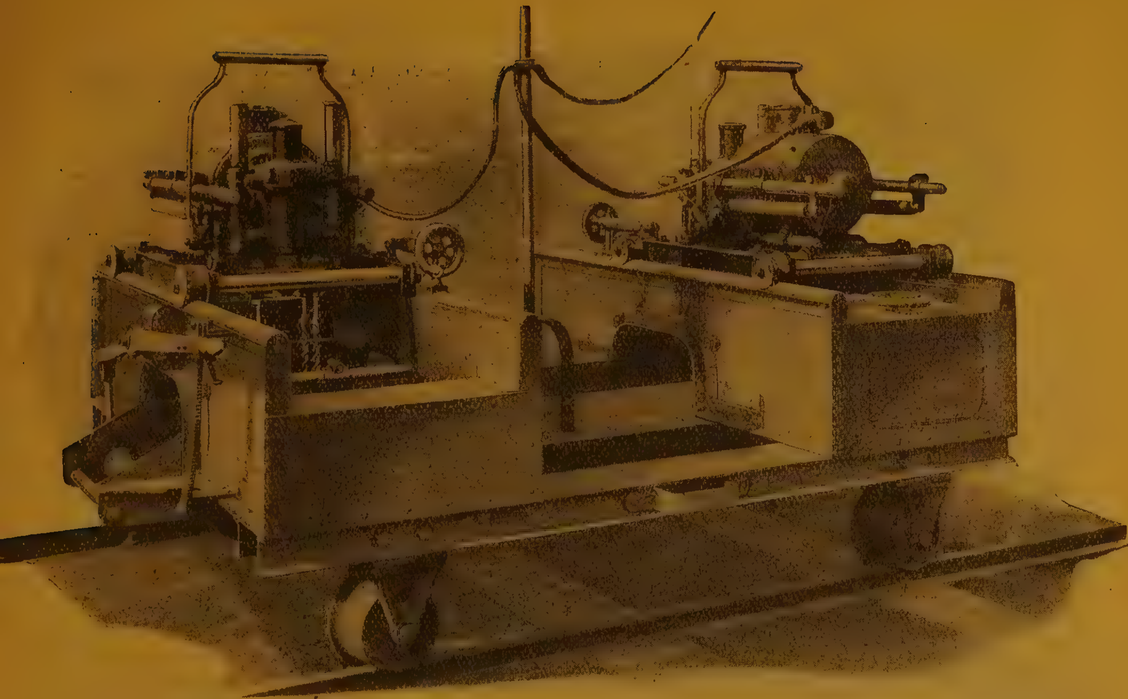


Fig. 2. — Multiple boring machine.

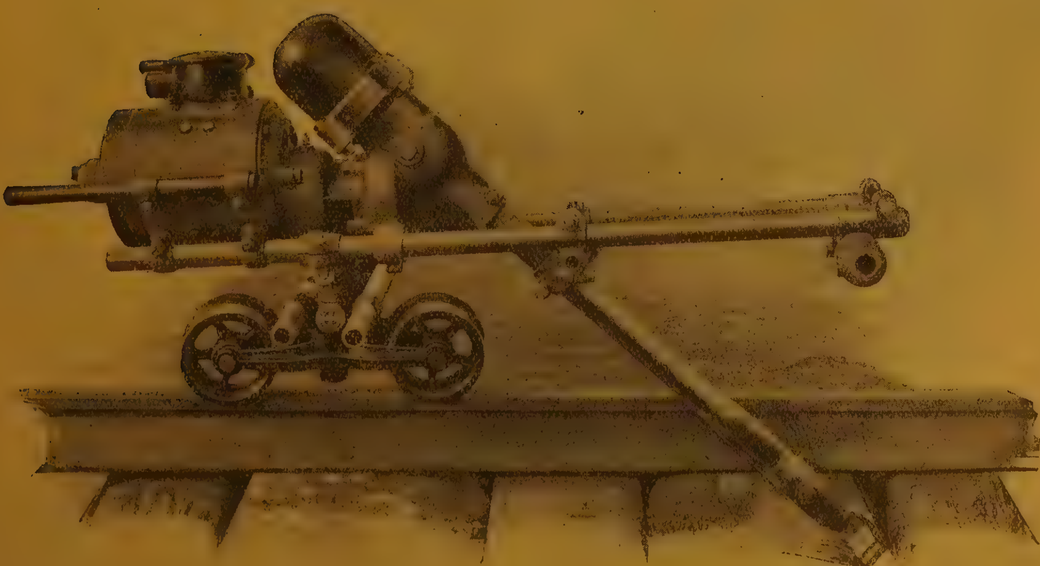


Fig. 3. — Packing machine.

Fig. 4. — A battery of packing machines at work.

newly packed road settles down to this highly desired condition. It therefore would seem that the useful line for consideration would be to find a method of materially shortening this time, and, in doing this, to assist in reducing the cost of this important part of permanent way work.

Considering the case of a satisfactorily packed road, we find that this is usually achieved only after the passage of many trains. The ballast beneath the sleeper is hard and in many cases almost like concrete, the mass being very highly consolidated. The spaces between the pieces of stone seem to have become filled up forming approximately a solid mass. With present day hand-packing one cannot expect to achieve this result at once, for although the intermittent blows of the beater will put the pieces of stone or slag close together, yet unless the blows are sufficiently strong to break the ballast, gaps are bound to be left between the larger pieces of material. It is for the filling up of these gaps that we have to wait for the settling of the line and shifting of the ballast under the passage of many trains; likewise this consolidating of the mass and filling up of air spaces causes the line to sink. If instead of the intermittent blows of the beater we use a series of blows so rapid that a *vibration* is set up, then the pieces of ballast move about sufficiently for the pressure behind to cause the smaller pieces to flow into the spaces between the larger lumps of slag or stone.

It thus appears that we must look to the assistance of vibration to gain what we desire in the securing of a well packed line.

From this it should not be assumed that vibration in itself, without the impact of repeated blows, is sufficient to render the ballast compact. The blow is essential, but the contention is that the blow does not become effective unless a vibration is set up to cause such movement of the ballast that the temporary

Fig. 5. — Method of removing machines from the track for the passage of a train.

increasing of spaces between pieces of stone allows the smaller particles to be forced through the narrow opening and so fill up the cavity behind.

To examine for a moment what we might call the consolidating force of the hammer after the vibration has been set up, it is found that the force required is considerable, and is far in excess of what could be readily supplied by human energy alone. If we are to carry out the modern idea of mind conquering matter, endeavour should be made as far as possible to place the man in the position of director of a machine that will carry out much of the heavier forms of his physical work. Applying this to the subject of packing, he will direct into the proper channels a suitable machine that will set up the required vibration and will give the rapid blows of sufficient strength.

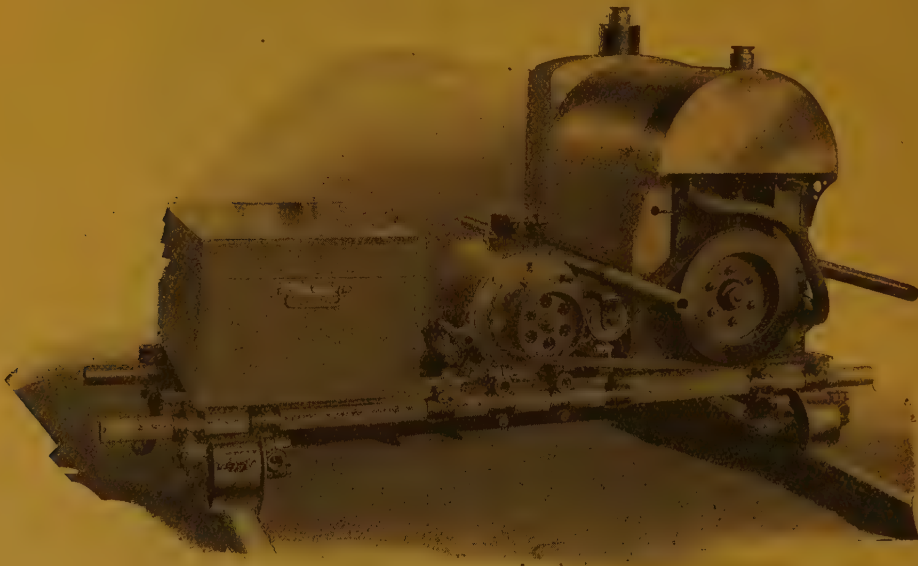


Fig. 6. — Small petrol-electric generating set.

Experience has shown that it is essential to have a machine much heavier than is generally considered necessary. This weight must be mechanically supported, but at the same time in such a way that it is available in connection with the blows.

As has been explained, the machine should be directed by the worker, though being of such a weight that he could not support it. The method of taking the weight is one of importance, but the solution that is at once apparent and which has been used successfully under varying conditions for some twenty years, is to support the machines on a small light trolley which readily moves along the line as work progresses, and which is moved off the track when such is necessary. Objection may be raised to the use of any form of trolley on a line, but it must remain for the railway companies to decide whether the advantages of a solidly packed line do not warrant arrangements being made for the use of a readily removable trolley support for a heavy type of packing machine. A question which may reason-

Fig. 7. — Packing sleepers on the Great Eastern Railway.

Fig. 8. — Screwing down chair screws, Redbridge, London & South Western Railway.

ably be expected to come to mind in connection with intense packing is that as to whether packing to such solidity will not tend to lift the track. Personally, I know of no instances where the track has been lifted through electro-mechanical packing, though the matter has been tested many times.

It should not be assumed, however, that if a battery of machines was put into operation definitely with the idea of lifting the track, and that adequate precautions were taken to prevent over-packed ballast from oozing out from beneath the ends of the sleepers, that one might not conceivably lift the track somewhat, but under normal working conditions — which really are the true conditions — the track is not lifted.

Under the heading of packing we are

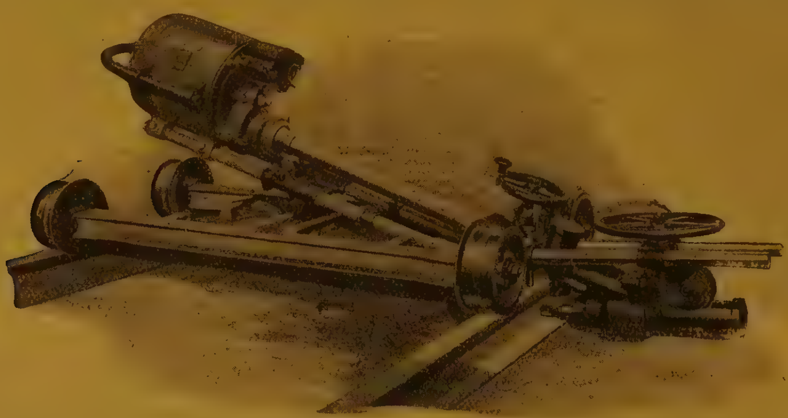


Fig. 9. — Rail drilling machine.

bound to consider the matter of ballast and the possibilities of packing various types by mechanical means. At once it may be said that no considerable difficulty is encountered in packing any kind of ballast. The point has been raised that a blow of the intensity required adequately to consolidate ballast would be so great that it would break up, if not pulverise, such substances as slag, for example. Again experience gives the answer and shows that such is not the case and that the ballast is packed without appreciably breaking up the slag or stone. In practice, slag or broken stone, and even sand have been successfully packed, while during the period of the war difficulty was not experienced in working on mine earth for railways in the war area. It should be pointed out however, that it is a study of not a little importance to secure the correct shoe to use with the hammer for each particular kind of ballast. In the case of broken stone the shoe is smaller and of quite a different design from that used for sand, and here it might be said that a remarkable degree of success has been achieved in the packing of sand where conditions have rendered the use of this necessary.

It is interesting for a moment to consider the intensity and strength of blows found desirable in electro-mechanical packing. 400 blows per minute are given by the hammer and the intensity of each blow is roughly 440 lb.; this is equivalent to 176 000 lb. blows per minute. If this is compared with the amount of work put into packing a sleeper by hand under present conditions, it is seen that there is much to be said for electro-mechanical packing.

Fig. 10. — Petrol-electric motor on the Great Eastern Railway.

Fig. 11. — Boring sleepers in sleeper yard, Redbrige, London & South Western Railway.

As there are four machines carrying out the packing of one sleeper at the same time, the work done on the ballast under the sleeper is something like 704 000 lb. blows per minute.

Fig. 12. — Extrahometre.

The necessity of having adequate weight in the machine has been emphasised, and this decision is the result of more than 20 years study of the subject, but regardless of this weight the entire packing battery may be removed from the track in about one minute.

A battery consists of four machines which work in pairs, the two machines of each pair packing opposite each other and in a special manner. The battery will pack very solidly from 40 to 60 sleepers per hour, which is equivalent to 10 or 15 sleepers per man per hour. However, it is important to note that this should not be compared with the output of sleepers per hour by a man working by hand as the result of electro-mechanical packing is many — very many — times superior.

It is not my intention here to go into the details of the financial saving that is possible through the use of the machines just described, as this would require too much of the time at our disposal — but there are a number of points that should be indicated for the sake of those taking up the investigation of this subject.

When working with an electro-mechanical packing battery :

1° The ballast is packed more firmly and uniformly than is possible by hand;

2° It is necessary to go over the line only once instead of having to come back several times after settling. This in itself is a great saving;

3° The line very seldom settles after packing;

4° Normal train speeds may be resumed immediately after packing is completed;

5° The Packing Battery can immediately follow the relaying gang and so the line is completely finished at one time;

6° There is greater security on curves and generally an increase of public safety;

7° The hammers have shoes specially designed for each kind of ballast;

8° As the man does not take the weight of the machine he can feel to a nicety when the sleeper is fully packed;

9° Similarly he can direct the blow where required with great precision;

10° As the packing is finished before the passage of a train the sleeper is not injured by being crushed on to the few sharp points of stone that frequently suffice to support it in the case of hand-packing;

11° Under proper conditions this is cheaper than by hand-packing.

A very interesting example of the satisfactory nature of the packing is shown in the case of a gun spur in France, which after electro-mechanical packing did not require to be repacked during the whole time that a heavy railway gun was fired from that position. I understand that such a case has never been achieved by hand-packing.

In one instance in Norfolk a length of line on a curve was electro-mechanically packed and a straight piece of road preceding it was packed by hand. It was found on examination after a number of hours that the hand-packed line had settled, whereas the curve, packed by machine, had remained solid.

It was just over 20 years ago that packing by this method was commenced in France on the Paris-Lyons-Mediterranean Railway. It was, however, due very largely to the interest in the development of modern track-work shown by Sir Henry Thornton and Mr. John Miller that the subject was recently investigated and tests made in this country.

Before terminating the section dealing with packing there is one aspect of the work that should be referred to, though it is more applicable to Indian and African Railways than to those in this country. I refer to the packing of steel sleepers. I think I am right in saying that considerable difficulty has been found in the past in getting a solid bed of ballast inside a steel sleeper. Where wood is used there is a fairly flat surface but with the hollow of a steel sleeper the ballast has to be forced up so that it comes into close contact with the base of the metal. Very excellent results have been obtained through electro-mechanical packing where, in the course of a few seconds, the vibration and force will give a more solid packing than is obtained by other means.

In a test that was carried out on the Prussian State Railways in Hanover, very excellent results were achieved packing at the rate of 40 seconds per steel sleeper.

Screwing machines.

At the present time the question of chair and rail fastenings is a very live subject. Of the many types that are in use at present, probably it will be best to concentrate remarks on the subject of coach screws with perhaps a word on through-bolts.

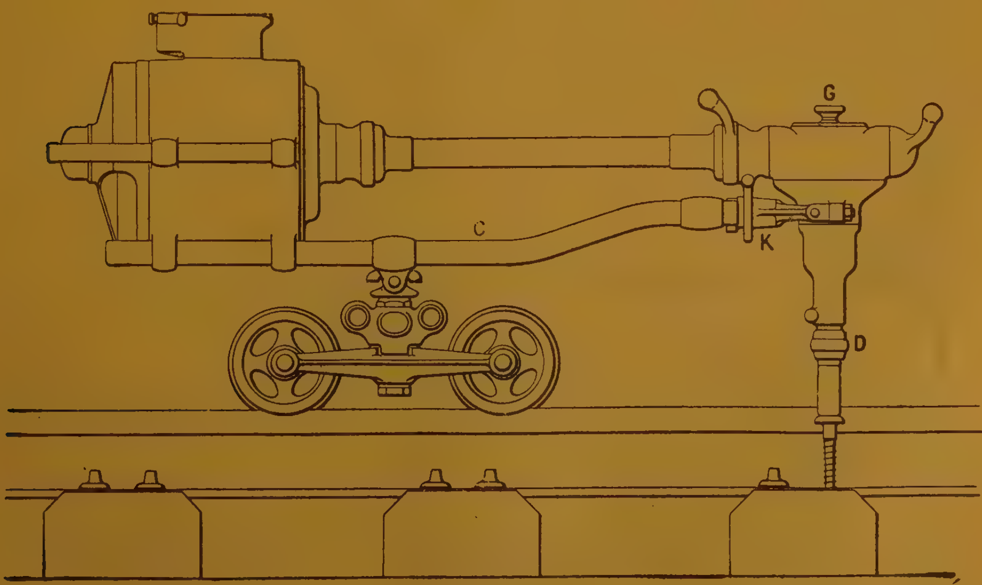


Fig. 13. — Screwing machine.

Hold of coach screws in sleepers.

TYPE.	Length, in inches.	Diameter, in inches.	Base of thread, in inches.	Pitch of thread, in inches.	Surface of screw.	Lubricant.	Sleeper.	Hole in sleeper, in inches.	Hold, in tons.
1. L. & S. W. R.	6	7/8	5/8	1/2	Black.	Nil.	Baltic fir.	1/2	4.22
2. — —	6	7/8	5/8	1/2	—	—	—	5/8	4.98
3. — —	6	7/8	5/8	1/2	—	—	Oak.	5/8	5.36
4. — —	6	7/8	5/8	1/2	—	—	Beech.	5/8	4.57
5. — —	6	7/8	5/8	1/2	—	Grease.	—	5/8	5.42
6. G. C. R.	6	7/8	5/8	1/2	Galvanised.	Nil.	Oregon pine.	5/8	4.76
7. L. B. & S. C. R. . . .	6 1/2	7/8	5/8	1/2	Black.	—	—	5/8	5.20
8. District	6	7/8	5/8	1/2	Galvanised.	—	Beech.	5/8	5.41
9. —	7 1/2	29 × 32	21 × 32	1/2	—	—	—	5/8	6.59
10. P. L. M. (France) . .	6	25 × 32	1/2	1/2	Black.	Oil.	Oak.	...	7.68

All screwed into sleeper to 2 inches from head except in 10, when screw is driven closer to head.

It is only now that the coach screw is coming into its own in this country, though its use abroad has been common practice for a number of years. It is used to some extent in America and particularly where the frost does not cause heaving of the track in winter. It has been estimated that up to 1915, 1 500 miles of track had been laid with coach-screws on the American Continent. General experience abroad has been with the Vignoles or F. B. rail, but as far as chairs are concerned there are the examples of the French State lines and the Paris-Orleans Railway.

The size of the hole bored in the sleeper before the insertion of the screws has a marked effect on the hold and this is a point which requires careful study. In soft wood a smaller hole can be used with advantage than would be desirable, say, in a hard oak sleeper. A certain influence on the selection of the right size of hole is to be found in the increased amount of energy required to put down a screw in a small hole; and this is sometimes allowed to influence the choice of size even with the knowledge that the hold under such conditions will be less than if the human factor was removed. Just before insertion in the bored sleeper the screw should be dipped in some substance which will act as a lubricant and protective agent. The substance selected may influence the size of the hole it is considered wise to use by rendering the operation of putting down the screw easier than otherwise would be the case. The subject of the hold of chair fastenings has been of considerable interest for a long time, and herewith is given the results of tests the Author has recently carried out, and which it is trusted will prove of value for future work.

A considerable difficulty encountered in the past in using coach screws and particularly where machines were utilised, has been the over tightening of the screw. One turn after the screw is

tight is sufficient to destroy the fibre of the wood on the inside of the hole, and so considerably reduce the holding power. There is also the point that when screws are used and the wood becomes softened or destroyed around the hole it is difficult to tell from visual observation whether or not there is sufficient hold to keep the chair or rail in position. This point has been dealt with under the heading « Mechanical Methodical Revision ».

The machine that has been devised to meet these somewhat difficult requirements is so interesting that it is worthy of some description. The electro-mechanical screwing machine is of a sister type to the packing machine, being operated on a light trolley along the line, one machine functioning at each end, *i. e.*, over each rail. In this way the machines are used to put down or unscrew screws along the line in position. The machines similarly may also be used at a base sleeper depot, or may be moved along the line to where sleepers are stacked. The mobility of this and the other machines is an important factor in saving the hauling of the material more than is absolutely necessary. The operation is extremely quick, and the turning torque that it is possible to exert is very great as will be seen from the use to which the machines were put during the late war.

At first sight it would seem that this great available turning torque, in itself, would be a danger in putting down screws where one turn too much would destroy the result desired. This, however, is not the case, for on the machine there is an adjustment so delightful in its action that the machine can be caused to stop at any desired predetermined hold to suit various classes of work, from the delicate operation of putting down a screw in a large hole in a soft sleeper to putting down a screw in a small hole in a hard sleeper. In its normal position the box spanner attached to the head of the machine is stationary but when this engages the head of the coachscrew, the machine automatically starts and functions until the screw is sufficiently tight (as previously determined) when the machine automatically stops. In operation the machines are very quick, for example, recently at a base depot where a pair of machines were in use (with two men) it was never found possible to supply sleepers to the machine sufficiently quickly to exceed the machine's output, though only two men were used in putting down screws.

Another important use is that in connection with the taking up of track where chairs have been fastened to the sleepers by means of coachscrews, it is possible by means of these machines quickly to remove all chair fastenings along a line, so that chairs and sleepers may be stacked or loaded separately, thus showing a great saving in handling, as also in space occupied in the trucks.

These machines, like the packing and boring machines, played an important part in France during the late war both with the British and French Armies. Great difficulty was experienced in removing screws from track that had been shelled or where the joints had been blown, as the hold of the screw in the wood was increased by the screws becoming bent. A method was devised by which these machines could be taken over shell holes and breaks in the track by means of temporary bridging, and even with these difficulties, and the extreme hold that the screws had in the sleepers, it was found possible to remove 28 000 screws in three days. It might be added that no more than seven men were used for erecting the temporary bridge work, operating the petrol-electric generating set as well as getting the entire plant along the track and collecting and stacking the screws. It may be noted that in one day when the machines were in operation removing screws for 6 hours 20 minutes the aver-

age of the two machines per hour was 1 284, which is something in excess of 20 screws per minute. This related to taking up demolished track, but it is interesting to note that at the same time in France where relaying was taking place with old sleepers from which the screws had been drawn, there were put down with two machines as many as 1 200 screws per hour or at the rate of 20 per minute.

A recent adaptation of the machine has been for tightening nuts on throughbolts. This work was carried out at a base depot. When the chaired sleepers came under the heads of the machines the nuts had been just started on the threads of the throughbolts. The function of the machine was to tighten these nuts at the same time drawing up the lower plate into the base of the sleeper. A matter of some 100 000 sleepers were so treated. Mr. A. W. Szlumper was the first to appreciate the value of these machines for British practice, and used them on the London & South Western Railway for chairing some 150 000 sleepers, some with coachscrews and some with throughbolts.

Sleeper boring.

It surely will be felt that little more can be added on the subject of boring machines, they are of so many kinds and have been used for so many years in almost every branch of woodworking that it would seem that the last thing had been said on the subject.

There are several lines of research that apparently have been missed by those specially interested in this branch of Permanent Way work.

There is first of all the machine boring of sleepers in position along the line, secondly, in order to save unnecessary handling of material there is the opportunity for boring sleepers at the stacks, whether this be at the principal sleeper depot of the railway or at stacks along the line where quantities may have been massed.

Next there is the question that is forcing itself upon Permanent Way engineers of the difficulties connected with the ordinary boring machines through the change over from the two holes required for some fastenings to boring three or four holes for trenails required for maintenance sleepers. The machines used to meet all these difficulties are again similar in general design to those for packing and boring They are operated on a small trolley along the line and are also removed from the track when necessary in about one minute. It is the matter of only a few seconds to change a drill say from a 5/8th to 1 1/8th, and this also includes the change of guide which is attached to the arm. This guide is used for centreing when boring sleepers, the chair itself being used as a template. It is likewise used for the same purpose when the boring is done through a special template at a base depot. Were Vignoles rails are used, the guide gives the correct distance of the hole from the edge of the foot of the rail.

Regarding the mobility of this plant, in a case where the entire plant including boring machines, and generating set, staging, etc., had to be moved from one part of a yard to another, the entire work took place and the machines were in operation within two hours. The machines are likewise quick in action for although each individual hole is bored separately, yet when six holes were bored per sleeper, the output was over 1 000 sleepers per day. This individual boring of holes is of great importance in connection with the lack of uniformity that is often found in cast chairs.

Frequently a very slight difference in the position of the holes in a chair may throw undue strain on the casting when the screw or other fastening is inserted. With the individual method of boring if desired the holes can be bored through

the actual chairs in position, thus assuring the true centreing of each hole.

It is not necessarily essential with these machines to bore an absolutely vertical hole, for in cases where an inclination is desired the machines can be adjusted to suit requirements. It is well known that with hand boring there is a tendency to produce an oval shaped and enlarged hole and this is entirely obviated by machine boring. The actual time taken is from two to three seconds per hole.

As an indication of the use to which these movable machines have been put when working at a base, it is interesting to note that they were used recently on the Northern Railway of France for boring 4 000 sleepers per day. This was in connection with the adzing machines referred to later.

In addition to the boring machine just described one of the multiple boring type is also very largely used. This is readily movable from place to place, though it is not used for working along the line. It is supplied with rail wheels and thus is easily moved from one place to another. It is generally operated on a siding close to stacks of sleepers. The output is about 1 000 sleepers per day. It is frequently used in conjunction with the large type of adzing machine when the sleepers move from the latter directly into this multiple boring machine.

Adzing.

The modern policy of removing the machines to where the work is located rather than using the additional labour of bringing the material to the machines, has caused the introduction of special machines for carrying out the operation of adzing. In many cases, probably more abroad than in this country, there is a considerable amount of re-adzing carried out, and frequently when this is done the sleepers are re-adzed in position, the machine actually being taken along the line and the new surface given to the wood without removing it from the road. This is found beneficial chiefly in two cases, firstly, when the chair or rail has worked itself into the sleeper unduly or unevenly, secondly, when the fastenings have become insecure and the old holes are plugged and new ones bored. This machine re-adzed the sleeper in 5 to 10 seconds.

The large adzing machine is in size and general manipulation very similar to the multiple boring machine. It is operated by two men, both ends of the sleeper being adzed at the same time. Any desired cut can be arranged, as for example the flat surface for chairs or the additionnal cutting to form a seat for F. B. rails. The cut in both the adzing and re-adzing machines is made by means of a high speed milling cutter, as it is found that in this way the wood is not torn as is so often the case with the ordinary adzing blades. The adzing machine has an output of from 1 000 to 2 000 sleepers per day for new sleepers. Naturally, this output is reduced when old sleepers are being re-adzed for future use, due to the fine particles of stone and sand that have become embedded in the wood.

It is a very considerable benefit in a sleeper depot to be able easily to move the adzing and boring machines from one stack to another and the sleepers feeding from the adzing to the boring machines considerably reduce the amount of labour necessary.

To take the case of the Northern Railway of France, the mothod adopted was to keep the adzing and boring machines together with their petrol-electric generating set, on the lines in the sleeper depot, so that they could readily change from one place to another. The empty trucks were then backed into the siding so that after passing through the machines the sleepers were at once mounted into the trucks for removal to the

creosoting cylinders : the whole space occupied from stacks to trucks, including adzing and boring was the matter of only a few yards.

Rail drilling.

Most of us have suffered in watching holes being drilled in rails with the hand ratched drill, or else we have suffered more in doing the work ourselves. This is perhaps not important where only a few holes are required, but if there are to be many the need of a power machine for doing this work in position is apparent.

The drill about to be described is not an adaption to railway conditions, but

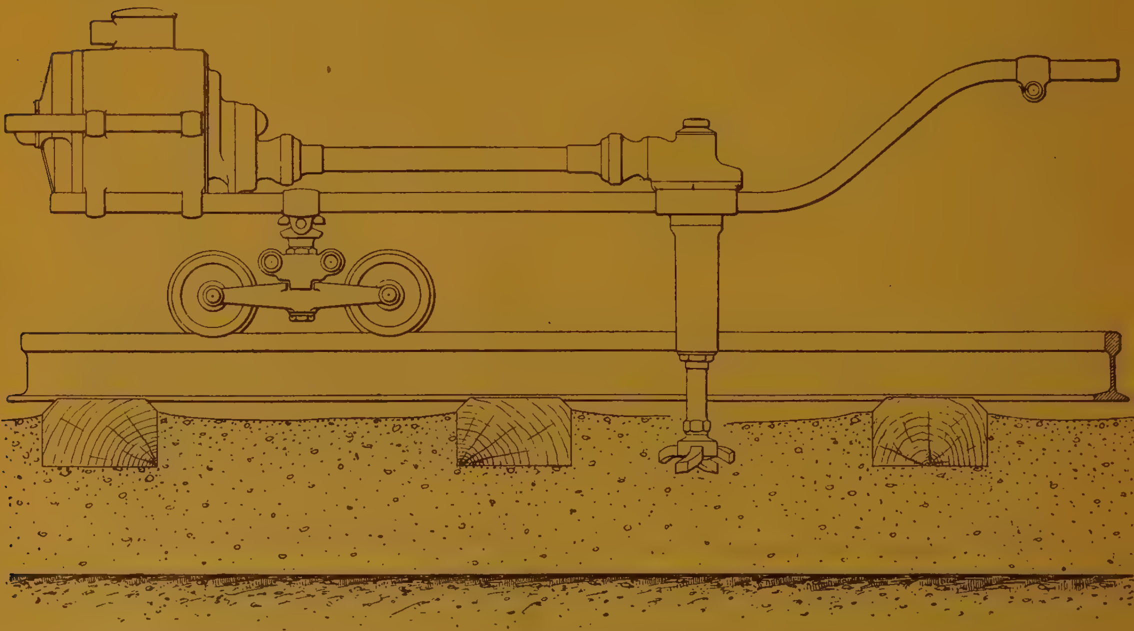


Fig. 14. — Ballast loosening machine.

is a machine designed specially for the drilling of rails, and which has been worked out under actual conditions of practical trackwork. The rail drill, like the other machines, is electrically operated, a motor of the required power being supplied with current from an electric generating set. The machine is carried on a light trolley, but in this case there is only one machine pivoted at the centre, so that either rail may be drilled as required. The drill works at 200 revolutions per minute and drills a rail in about 30 seconds. In actual practice the output is about 40 holes per hour, or on an average about one every 1 1/2 minutes, the extra time being taken up in moving the machine, etc.

The value is not alone in drilling holes for fishbolts, for it has a very important use in drilling holes for bonding rails for electric traction.

There are two types of rail drill, one working from the outside and the other pattern working from the inside of the rail.

Rail sawing.

The need of a new type of rail saw became apparent during the late war, and this was the cause of the careful study that was made of this matter. As a result, a readily movable power driven rail saw was introduced for use along the line, and this has met with considerable success.

Blades of the hacksaw type are used, and a rail is cut through in from 6 to 10 minutes, leaving a square and clean cut face.

Loosening ballast.

So much energy has been expended in pick work on hard consolidated ballast that one cannot but wonder that a suitable machine was not brought out previously for loosening ballast ready for removal by shovel.

The individual machine, which is mounted on a trolley, is moved along the line and rapidly stirs up and loosens the ballast between and around sleepers. As the machine is quick in action there results a considerable saving in both time and labour.

[656 .253. (01]

Some fundamentals of train control, (1)

By F. L. DODGSON,

CONSULTING ENGINEER, GENERAL RAILWAY SIGNAL COMPANY, ROCHESTER, N. Y.

Figs. 1 to 10, pp. 944 to 952.

(*Railway Review.*)

Our governement has been interested in the subject of automatic train control for nearly seventeen years. The first step in this direction was taken by the Congress in June 1906, when by joint resolution it directed the Interstate Commerce Commission to « investigate and report on the use of, and necessity for, block signal systems and appliances for the automatic control of railway trains in the United States ». I have quoted the exact words of this resolution in order to show that at this time the Congress had block signals in mind as well as automatic control devices. As a result of the report made by the Interstate Commerce Commission in compliance with this resolution, certain appropriations were made and a special board known as the « Block Signal and Train Control Board » was created. Again, please note the term « block signal ». For five years this board carried on extensive investigations of train control devices and the conclusion which is reached was, to quote the language of the Commission :

« That the information obtained from tests together with knowledge of the general state of development of the art of automatic train control, showed that there were several types of expedients and methods of application which if put

(1) Substance of a paper read by Mr. Dodgson before the Central Railway Club, at Buffalo, N. Y., 8 March 1923.

into use by railroads, would quickly develop to a degree of efficiency adequate to meet all reasonable demands, and that such devices properly installed and maintained would add materially to safety in the operation of trains. »

This board went out of existence in June 1912, but before doing so, they presented to the Commission a list of eighteen automatic train control devices « which is considered to possess sufficient merit to warrant tests under operating conditions ».

For one year only the activities of the commission along these lines lapsed; then in October 1913, after having received further appropriation from the Congress, the duties of the block signal and train control board were assigned to the division of safety of the commission. The work of this division, which was later known as the bureau of safety, was somewhat interfered with during the war; but nevertheless by 1919 it had made tests of, and reports on, various types of devices and the conclusions which they reached differed in no essential from those reached by the older board. In fact they emphasized the need of train control and strongly recommended further development work. It is said that it was due to the recommendations of these two bodies that Section 26 was included in the Transportation Act of 1920. As this is the law under which the commission is now acting. I will quote it in full. It provides :

« That the Commission may, after investigation, order any carrier by railroad subject to this act within a specified time in the order, to install automatic train-stop or train-control devices or other safety devices which comply with specifications and requirements prescribed by the Commission upon the whole or any part of its railroad, such order to be issued and published at least two years before the date specified for its fulfillment. »

Heré, now is a different state of affairs as far as the railroads are concerned. While before, the Commission, by virtue of its instructions from the Congress, had been empowered only to investigate, test, report, conclude and recommend, it now has the power to compel actual installation and use of these devices. Note, however, that the term « block signals » is entirely absent, unless it can be considered to be included in the term « other safety devices ». Following the enactment of this law, in order to fully carry out its provisions, the Commission invited the American Railway Association to cooperate with them in à review of the investigations of the past, and a check on the actual performance of such devices as were in actual operation. As a result of this invitation, a joint committee on automatic train control was appointed in November 1920. This committee consisted of representatives from the signal section, the operating, engineering and mechanical divisions of the American Railway Association, a body of men most prominently fitted to deal with this very complicated problem. After about a year's work this committee submitted a report in which they gave a very complete and concise set of requirements and specifications for train control; and the gist of their conclusions was, that while some of the devices which they had investigated showed special merit, more time was needed to demonstrate their practicability in actual railroad operation.

The next step in this series of events which I have been chronicling was taken on 10 January 1922, when the Interstate Commerce Commission, acting under the power given them by Section 26 entered an order under which certain carriers, 49 in all, were given an opportunity to show cause why they should

not be compelled to install automatic train stop or automatic train control devices upon certain portions of their lines. In entering this order the Commission expressed the opinion that the devices which they were ordering into general use had reached a stage of practical development much further advanced than was the automatic coupler and the airbrake, when the Congress by enacting similar laws ordered their general use. The Commission also pointed to three systems in use on three different railroads which were said to be giving entire satisfaction. These two statements of the Commission were most vigorously contested by the representatives of the carriers at the hearing which was held during the month of March 1922. It was further pointed out by these representatives that the moneys (which some claimed they dit not have) required for the fulfillment of the order, could be used to much greater advantage for the « other safety devices » mentioned in Section 26.

Nevertheless, on 13 June 1922, the Commission decided that the order should stand, so that at the present moment 49 railroads of the United States find themselves obliged to select and install some kind of an automatic train device on at least one full passenger locomotive division, and on or before 1 January 1925, every engine operating over the division must be controlled by that automatic device. Whether or not such additional safety devices are necessary, or whether or not the devices available for the purpose are sufficiently developed for practical use, are questions which are not now important, and need not be discussed at this time, for they have already been decided in the affirmative by our law makers. The question which is important at this moment, particularly to you gentlemen who may be charged with the duty of selecting a device for your railroad or who may be responsible for the operation of the device or for the operation of the railroad after the device is in use, is, what kind of a device will fulfill your obligations to the Commission?

Naturally, to answer this question we must refer to the order itself, for in the order are set forth certain specifications and requirements which must be met. It has been said that these specifications are very vague and misleading, and that they are capable of many different interpretations. Personally, I do not think so. To my mind these specifications, when read as a whole and with a clear understanding of what is wanted, describe very concisely and clearly certain systems which will, in the opinion of the Commission, provide the necessary degree of safety in railroad operation. Of course, the primary object is safety, and the commissioners say that this can be accomplished by enforcing obedience to fixed signals. They do not, however, and perhaps very wisely too, say this is the only way in which the requisite amount of safety can be provided, thus leaving the way open for the development of some other kind of a signal system. This at once suggests « cab signals ». The Commission, however, do not mention cab signals. They simply say that « the feasible operation of essentially similar devices used without working wayside signals may be regarded as a possibility ».

We will consider tonight only those systems which are to be used with and may be considered as adjuncts to the present system of fixed signals, for I feel sure time will not permit us to consider cab signals, or whatever it was that the Commission had in mind when they used the expression which I have just quoted.

Broadly speaking, the Commission has given you the choice of two very distinct classes of systems, and in their definitions they have defined them as :

1° Automatic train stop, and
2° Automatic speed control.

The difference between these two classes is that in the first one, the automatic train stop, the train is to be stopped before it reaches the point of danger; and in the second, the automatic speed control, the speed of the train is to be reduced to some prescribed rate before it passes the point of danger. In considering systems which are to be adjuncts to fixed signals, the point of danger is a signal in the stop position.

The specifications do not say how far from the signal the train shall be stopped, or at what speed it shall be running when it passes the stop signal; but they do say very distinctly that the devices « shall be operative at braking distance from the stop signal location if signals are not overlapped, or at the stop signal location if an adequate overlap is provided ». This is certainly very definite and concise and leaves no doubt as to the point at which the device shall begin its operation. In other words, it gives us what may be termed a starting point for our systems.

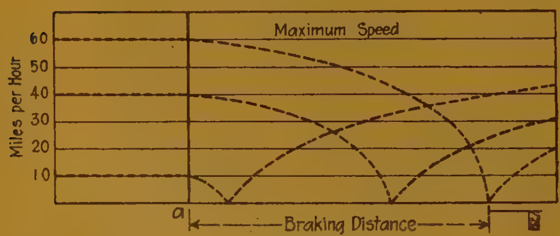


Fig. 1. — Automatic train-stop.

It is very hard to visualize things of this kind from words only. I have, therefore, prepared some simple diagrams which I believe will add materially in giving a clear understanding of the different systems. The first of these diagrams represents the automatic train stop system. In this diagram, as in the others which will follow, the heavy black lines denote the speed restriction which is to be enforced, and the amount of speed is represented by the vertical distance above the horizontal line. The horizontal line may be taken to represent the track. The dotted lines in the diagrams represent the speed of the train as it proceeds along the line. We will assume that when this dotted line crosses the speed restriction line, the device, whatever it may be, is brought into action, and the speed of the train is affected in the manner prescribed by that particular device.

The automatic train stop is defined in the specification by these words: « Without manual control by the engineman, requiring the train to be stopped, after which the apparatus may be restored to normal conditions manually and the train permitted to proceed. »

The only way we have to stop a train is to apply the airbrakes; and the only way in which we can insure that the train can not proceed until it has been stopped, is to keep the brakes applied until the train has stopped. The action of the devices in this case then, must be to apply the brakes, and it must be done without any manual control from the engineman. In other words, the engineman must be powerless to prevent such an application. Furthermore, the device must be so organized that the engineman can not release the brakes until the train has come to a stop. There is in this case, no speed limits. The device must function at all speeds. This makes our speed restriction line a vertical one extending from maximum speed to zero speed. And in our diagram it must be located braking distance from the signal, if there is no adequate overlap, or at the signal if there is an overlap.

We can now see what happens to a train operating under this system when it is approaching a stop signal. If the train is running at maximum speed, say 60 miles per hour when it passes the point *a*, or in effect crosses the speed restriction line, its speed is at once reduced and it will come to a stop at the

signal. After coming to a stop it may proceed without any speed restriction other than that which may be imposed by its own power. Again, should the train be running at a lower speed, say 10 miles per hour, the brakes will be applied and it will be stopped in a much shorter distance; and after being stopped it may proceed as before and pass the stop signal at any speed which its power will permit it to attain. In other words, with this system when the signal in advance is at stop, the brakes must be applied when the train passes the point, no matter what its speed may be. The brakes can then only be released by the engineman of fireman getting to the ground, after which all control ceases until another point similar to point *a* is encountered. So much for the present for the automatic train stop system, or the « plain » automatic stop as it is sometimes called.

Under the class which I have just designated as automatic speed control, the commission gives you the choice of at least three systems. In the specification, under the heading « functions » they use these words :

« The following features *may* be included separately or in combination, in automatic train stop or train control systems. »

I have already quoted the feature which applies to the automatic train stop, and in that case there was only one, but under automatic speed control there are four features; and as they may be used separately or in combination, we would expect to be able to build up four systems when they are used separately and when each feature is used in combination with the others, we would be able to build up ten systems. This, however, is not exactly the case. We will first consider the systems when these features are used separately.

The first feature relating to speed control is described as follows :

« *a*) Automatic stop, after which a train may proceed under low speed restriction until the apparatus is automatically restored to normal or clear conditions by reason of the removal of the condition which caused the stop operation. »

As a matter of fact, this system differs from the system represented by figure 1, or the automatic train stop system only in that after the train has been stopped, its speed is to be restricted until normal conditions again exist; that is, until the train is again running under proceed signals. To construct a diagram to represent this system, it is only necessary to add to figure 1 a line to represent the speed limit after the train has been stopped. This is the heavy horizontal line shown in figure 2 as 10 miles or so above the base line.

Again, as in the system represented by figure 1, the brakes must always be applied, when the train passes the point *a*, if the signal in advance is at stop, irrespective of the speed of the train at this time. Further, as in the system represented by figure 1, the train must come to a stop before it can proceed; but in this case, if it then exceeds a certain speed, the brakes will again be applied and the train brought to a stop. It can again proceed but will again be stopped if it exceeds the prescribed speed. This condition must continue until the train is again running under clear signals.

Feature *b* reads as follows :

« *b*) Low speed restriction, automatic brake application under control of the engineman may, if alert, forestall application at a stop indication point or when entering a danger zone and proceed under the prescribed speed limit, until the apparatus is automatically restored to normal or clear condition by reason of the removal of the condition which caused the low speed restriction. »

This simply means that if the engine-

man, by the proper control of his train brings it to the prescribed speed before reaching the point *a*, no automatic brake application will take place. In other words, in the diagram which would represent this system (fig. 3), the vertical speed restriction line would not extend below the prescribed low speed limit. Trains operating under this system could, therefore, pass the point *a* without automatic brake application, if the speed at the time they passed the point was below that prescribed. If, however, the train is not below the prescribed speed when passing the point *a*, the automatic device will act just the same as it acts in the other systems which we have described, and the train must come to a stop, after which it may proceed under the same conditions as represented by figure 2.

It would be permissible to allow the

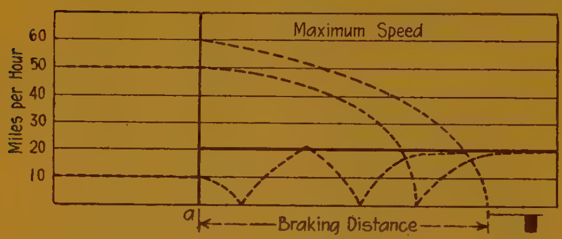


Fig. 2. — Speed control (*a*).

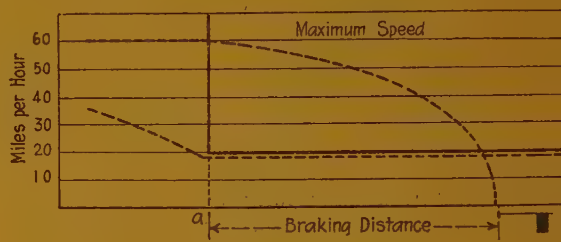


Fig. 3. — Speed control (*b*).

brakes to be automatically released when the speed is below the prescribed rate, and thus theoretically allow the train to proceed at the prescribed rate without stopping. I will, however, have something to say about the releasing of brakes later.

Feature *c* is quite different from *a* and *b*, and is perhaps the most important one of the four. It reads as follows :

« *c*) Medium speed restriction, requiring the speed of a train to be below a prescribed rate when passing a caution signal or when approaching a stop signal or a danger zone in order to forestall an automatic brake application. »

Put in plain words this means, that if an engineman controls his train as he approaches a stop signal so that by the proper use of his brakes he is at all times able to stop his train at the signal, or to pass it at a prescribed low speed, then, and only then, will an automatic brake application be avoided. In other words, the engineman is compelled to obey the signal indications which, as the specifications say, is the « primary function of automatic train stop or train control devices ».

Figure 4 is a diagram which represents the system which would be built up under feature *c*. The speed restriction line in this case is quite different from the others. If the train is below maximum speed at the point *a*, the devices will not act; and if at any other point between *a* and the signal it is at a speed

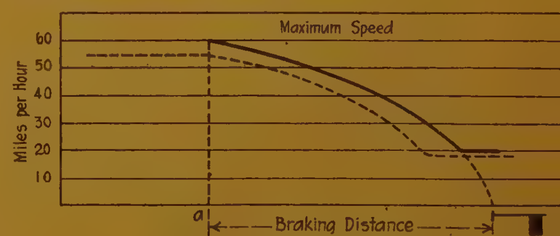


Fig. 4. — Speed control (*c*).

below that which the brakes if automatically applied would bring it to a stop at the signal, the devices will again not act. Technically speaking, this speed restric-

tion line is the braking distance curve for the particular train which is being considered and the particular locality. The operation of trains under this system is so obvious that it need not be referred to further.

The fourth feature to which the Commission has referred is not, I believe, intended to be used separately, but always in combination with one or more of the others. It reads as follows :

« *d*) Maximum speed restrictions providing for an automatic brake application if the prescribed maximum speed limit is exceeded at any point. »

This really provides a means for enforcing a maximum speed limit at all points along the line, and it is quite obvious that if this limit was placed low enough, a system would result which, as far as safety is concerned, would equal that of any of the others. It would, however, place such a restriction on operation that its use would be out of the question. It may be quite useful, however, when used in combination with one or more of the others, and in that connection it will be referred to later.

The various combinations which can be made of these features need not be referred to at the present time. Later in discussing some of the better known proposed systems, some of these combinations will be brought out.

Such are the fundamentals of the system which the commission has outlined as being capable of meeting their requirements as to safety, and the carriers are allowed to take their choice in fulfilling their obligations under the order. In making this choice, however, there are a great many important things to be considered; so many, in fact, that volumes could be written upon the subject. But at this time I want to call your attention to only a few points which in my opinion need the most careful consideration. First, is the system one in which the train control device is purely an adjunct to the fixed signals, or, in other words are the signals necessary for the proper control of trains?

Signals, as we all know, add immeasurably to the safety of railroad operation; and if the train control system which is to act in conjunction with them is so organized that it tends in any way to decrease the safety provided by the signals, then most assuredly a backward step is being taken in adding the train control.

I wonder if you gentlemen realize the comparative reliability of the modern automatic block signal. There is an old saying that nothing is sure except death and taxes. I sometimes think automatic block signals come next. When I say to you that there are block signals being operated today where the stop failures are less than one in sixty thousand operations, and that the false clear failures are something like one in four million operations, you recognize the large figures, but I am afraid you hardly realize what they mean. If, however, I were to illustrate these figures, by assuming a railroad built around the earth with a modern automatic block signal each mile, these figures would mean that on the average a train would travel on this railroad about 2 1/2 times around the earth before it encountered a signal which told it to stop when it should not stop, and that before encountering a signal which told it to proceed when it should not proceed, it would have to travel 175 times around the earth, you will then, I believe, realize the high degree of efficiency to which these devices have been developed. This development has taken a great many years, and while train control devices will no doubt ultimately be developed to the same degree of efficiency, it will take some years, at least, so that if during the development period, the enginemen rely on the train control devices to keep themselves out of trouble, the net re-

sult can not help but be a decrease in safety. It is most important, therefore, that when the train control device is in operation the engineman must still rely upon the signals in order to properly control his train.

The next important point to be considered is what kind of a brake application is to be made by the automatic devices. Up to a comparatively recent date it has been considered by inventors and promoters of train control devices that all that was necessary in order to make an automatic brake application was to find some way to vent air from the train pipe. This is true, particularly if enough air is vented, as all you railroad men know, to your sorrow sometimes, when you think of burst air hose. But it is hardly a practical way to make a brake application. On passenger trains and on short freight trains a full service application will rarely produce bad or rough stops, but on long freight trains particularly at low speeds, a full service application will, as all of you know, always make a rough stop, and, under some conditions, might make a disastrous one. In order that you may realize just what it means when the brakes are applied on a long freight train, I am going to show you some brake cylinder cards recently taken on a 100-car freight train. These cards are the average from several tests, and are taken with a seventy pound train line and a full service application, and they show the pressures in the cylinders on the first, 25th, 50th, 75th and 100th car. You will note for 15 seconds after the application is started, there is no pressure in any cylinder between the 50th and the 100th car. In the same time the pressure in the first car has reached 27 pounds or 40 % of the normal pressure. If this application had been made when a train of one hundred empty cars was traveling at a speed of 25 miles per hour, on a level grade, at the end of the fifteenth second after the start of the application, the first car, if left to itself, would have been traveling about 10 miles per hour, while the last 50 cars, if left to themselves, would be traveling nearly 20 miles per hour. The first car, if left to itself, would travel 325 feet and the last cars, if left to themselves, 438 feet.

You can imagine the strain which must be absorbed by the draft gears under these conditions, particularly when you realize that the total spring draft gears would be only a little over 20 feet for the first 50 cars. Again if this application had been made when the head car was ascending a 1 % grade and the rear cars ascending a 1 % grade, the rear cars at the end of the 15th second would have tried to travel about 22 1/2 miles per hour, while the first car wanted to travel about 7 miles per hour.

I will now show the cylinder cards for the same cars when the train line reduction was 15 pounds and you will note that the difference between cylinder pressures for the first 15 seconds is very little, if any, different from what they were with a full service reduction. If I had a set of cards for a 10-pound reduction to show you, you would still find very little difference in these cylinder pressures. A 7 1/2-pound reduction, however, will show a quite material difference. Of course, with a lesser number of cars in the train this difference in cylinder pressure would be less and the shock during in application of the brakes correspondingly less; but I believe all air-brake experts will agree that a full service application or even a single 15-pound reduction on freight trains of over 50 cars is at least not good practice and should be avoided if possible.

The reason for these severe shocks during the application of brakes on freight trains is quite obvious. The cylinder cars tell the story. They also clearly suggest the remedy, that is, apply the brakes on all cars at the same

time or have solid connections between the cars. The first of these remedies means an entirely different braking system, and the second would be absolutely impossible, for several reasons. The cylinder cards also suggest the next best remedy and that is to have as little difference in cylinder pressures as possible during the first part of the application. This requires a low train pipe reduction at the start of the application. The draft gear slack will thus be caused to run in or the cars to bunch, as it is more commonly called, with a minimum amount of shock. As the cylinder pressures begin to equalize throughout the train, the slack will run out and if another reduction is made after the slack has all run out, there will be the same amount of shock, but if the second reduction is made when the slack is all in, it can be comparatively heavy reduction without causing undue shock. This method of braking, is as you know, the universal practice on all railroads, not only with long freight trains but on all trains, passenger as well as freight and the reason for this practice is quite clear from what I have shown you. It is also quite clear that the smoothness of a stop will depend very largely on the time allowed between reductions, and it is also quite clear that this time will depend upon many things, not only on the class, lenght, and make-up of the trains; but also upon the contour of the track upon which the train may be running, and also in a somewhat lesser degree upon the action of the brakes themselves. So, when we see or feel a rough stop, we should not always blame the engineman, for it may have been due to some cause over which he had no control.

Now it is perfectly possible to automatically make a brake application on either a freight train or a passenger train with any amount of train line reduction desired. It is also possible, although perhaps considerably more complicated, to make a split application automatically, but I leave it to you gentlemen, is it possible even with all the ingenuity that mortal men possess to make an automatic device which will make a brake application which will be proper under all the varied conditions under which such applications have to be made. Man has made some wonderful automatic devices, but he has never yet made brains, and brains and good ones too, are required to make these applications properly.

It would seem, therefore, that it would be quite impossible for you to select a train control system in which the automatic brake applications are properly made on all trains. Unfortunately, if you happen to be connected with one of the 49 carriers mentioned in the Interstate Commerce Commission order, this fact does not relieve you from the duty of making a choice, so you will naturally look for the next best or perhaps more properly, but somewhat ungrammatically speaking, the next least worst system. If this system is one in which there will be a great number of these automatic brake applications, and I would consider a great number to mean every time a train ran through a caution block, it would seem that a low train line reduction of not over seven and one-half pounds would be the only safe one to make. This, however, brings in another complication. The braking distance of a train is almost inversely proportional to its braking power. A seven and one-half pound train line reduction will give less than one-half the available braking power. Hence, the braking distance will be more than twice as long as it would be if the whole braking power were used. It is quite evident that such a system would place a handicap on the capacity and operation of any railroad. On the other hand, if the system selected was one in which these automatic applications were very few, then it is pos-

sible that even a full service application could be tolerated. In my opinion this is the best solution that can be made of very complicated problem; and in order to have automatic application occur as few times as possible, I should say that one of the most important fundamentals of a train control system is to have the system so organized that an automatic brake application will take place only when an engineman fails to properly control his train when approaching a stop signal.

I want to say just a few words about releasing brakes on long freight trains, for this question will be a very important one in determining the speed limitations which should be used in applying speed control to railroads. I will show you the brake cylinder cards during the release of brakes on a 100-car train after a full service application. You will note that the 100th car does not begin to release for nearly 30 seconds after the release has started. The retarded release action of the K-2 triple valves is quite prominent on the first car, but is noticeably absent on the other cars. When a release is made on a train of 100 empty cars when it is moving at a speed of 15 miles per hour, on a level grade, the first car at the end of the 15 seconds would, if left to itself, be just about moving, and would have traveled about 130 feet. The fiftieth car, if left to itself, would stop in about 90 feet, and consume about 6 seconds in so doing. Even if the release on this train was started when the speed was 20 miles per hour, the cars between the 50th and 100th, if left to themselves, would stop in about 165 feet and in a little over 10 seconds, or some 20 seconds before all the brakes were released. If we consider this 100-car train to be loaded so that its total weight is 5 000 tons, the nominal braking power would be only 24 % instead of 60 %. Nevertheless, if the release was started when the speed was 20 miles per hour, after a full service application, the train would still be stopped before the brakes were fully released on the rear cars. On trains of this kind it would seem that it is impossible to release the train brakes without bringing the train to a stop unless the speed at the time the release started is considerably higher than these trains usually run. With shorter trains and lighter brake applications, the conditions during the release of the brakes are, of course, quite different; but I think I have said enough on this subject to show the importance at least of giving it consideration.

I will now briefly discuss a few of the systems of train control which have been proposed, describing them only as they apply to control diagrams similar to those which I have already shown you.

Figure 1 represents all of the so-called plain automatic stops which conform to the Interstate Commerce Commission requirements. Types of this system have been proposed where the automatic devices would not be operated if the speed when passing the point *a* was below a certain prescribed amount. Another type of this class has been in use for some time in which the engineer may, if he so desires, annul the operation of the device when passing or after he has passed the point *a*. I understand, however, that the Commission has definitely refused to approve of this type. Let us hope that they will be more lenient if they are asked to approve the other modification which I have mentioned.

So far as I know, no systems of the types illustrated by figures 2 and 3 have been proposed. Systems of these types require a speed measuring device to be carried on the train. When such a speed measuring device or speed governor is once provided it is a simple matter to amplify the system so as to make it more applicable to railroad operation. I will only refer to one such system. It is illustrated by figure 5.

This system as I have shown it is one of the intermittent contact types, although the same scheme of control could be secured by either the intermittent inductive or the continuous control devices. There is a ramp or control point located in the rear of each signal; and this system is so organized that when a train passes a control point in the rear of a caution signal, a certain medium speed limit is set up. If this speed is exceeded before the train reaches the control point in the rear of the home signal, the brakes will be applied. When the train passes the control point in the rear of the home signal, a lower speed limit is set up which will continue in effect until a control point is reached where, by reason of the condition of the signal, either a medium or a high-speed limit can be allowed. It is only necessary that these control points be placed braking distance for the medium speed, instead of braking distance for the maximum speed, from the signals. In this type of system it is a very simple matter to introduce feature *d* to which I referred when discussing the requirements of the Commission. With feature *d* added to this system, trains controlled by it would have to run below a fixed maximum speed through a block which it had entered by passing a proceed signal, and to avoid an automatic brake application, it would have to be below a certain speed before passing a caution signal. It would have to remain below that speed while running through that block and finally be below a certain fixed lower speed before reaching the stop signal.

Another type which is proposed, and is quite prominent, makes use of the speed restriction line shown in figure 4. In order to accomplish this it requires on the train, in addition to a speed measuring device, a distance measuring device. These two measuring devices are so interrelated that when the train passes a control point in approaching a stop signal, the speed limit which is enforced decreases as the train nears the signal. This is perhaps the most ideal scheme of control that has been proposed, but unfortunately it has certain limitations. You will remember that I said that this speed restriction line in figure 4 was technically a braking distance curve for the particular train and block considered. The shape of this curve, and more particularly its lenght, will depend upon the grade, not so much perhaps when only passenger trains are considered, but very greatly when heavy freight trains are to be dealt with. It is possible to so control the interrelation between the two measuring devices on the train that any speed line will be produced; but this control must be made to fit the grade of the block in which the train is running.

This is also possible and has been done, but at the expense of a great deal of mechanism and complication. To avoid this complication it is proposed to have the measuring device produce only one curve; but to divide this curve into two parts, one part forming the speed restriction line between maximum and a medium speed, and the other part the speed restriction line between medium and a low speed; and then in applying the system arrange to bring into action these speed restriction lines at such points as are required by the grade.

Figure 6 is a control diagram of this system as it has been proposed. The two curved portions of the speed restriction line are portions of the braking distance curve required for the shortest block to be encountered. They are produced by the two measuring devices and the horizontal portion of the speed control line is produced by the speed measuring device only. The first part of the speed restriction line is brought into action when a train passes a caution signal and the second part when the train passes a point located at a proper braking distance from the stop signal.

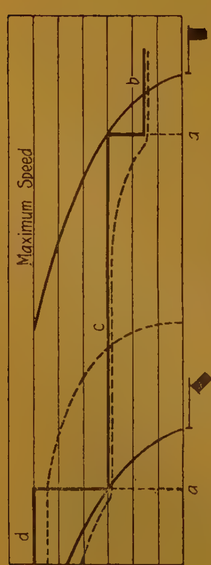


Fig. 5.

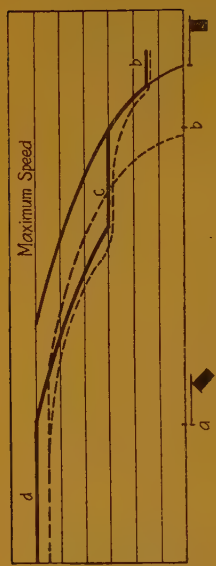


Fig. 6.

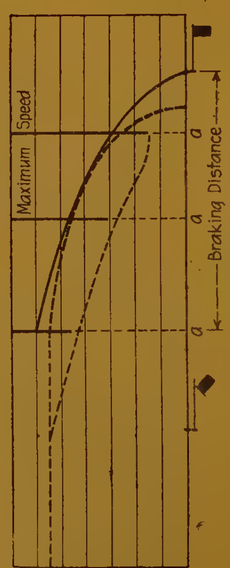


Fig. 7.

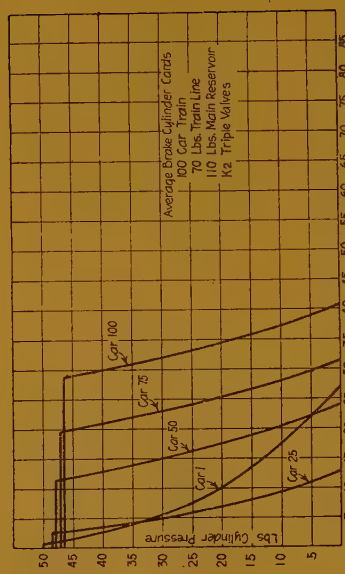


Fig. 8.

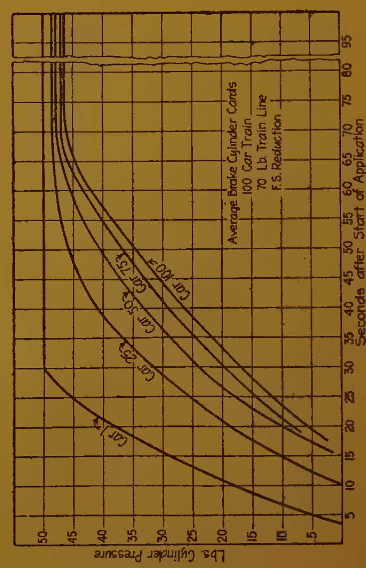


Fig. 9.

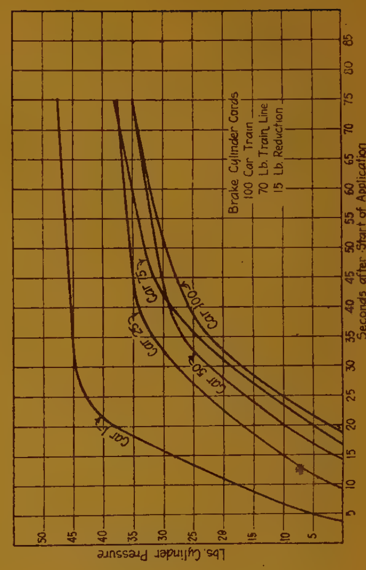


Fig. 10.

Still another type which is proposed for making use of the control line shown in figure 4 is practically a modification of the device required to produce the simple vertical speed restriction line of the plain automatic stop system. This modification consists of so organizing devices carried on the train and devices fixed on the right-of-way that the automatic brake application will take place only when the speed of a train by a control point exceeds a certain fixed amount. Such a system is very simply illustrated by figure 6. The light line curve is the actual braking distance curve for this particular block. By being able to fix the speed at which a train may pass a control point without receiving a brake application with a change in the arrangement of the right-of-way devices only, it is possible to easily fit the system to any grade, in other words, each block can be engineered on its own merits and the greater the number of control points used, the nearer a train can run to the maximum possible speed restriction line without receiving an automatic brake application.

[385. (09 (.42)]

The railway position.

(*The Engineer.*)

We have, on many occasions in the past, spoken of our railways as being administered by very capable men. The truth of this remark has never been better exemplified than in the results of last year's workings, which were far more satisfactory than they were expected to be. As the first seven and a-half months of 1921 were under Government control, no comparison between that year and last year can reasonably be made. Using, however, reports for the year 1913, we have compiled the instructive accompanying tables. They show that whilst the increases in rates and fares and in other charges have raised the receipts from railway working for the seventeen principal companies to 97.39 % above those of 1913, yet the expenditure of the same companies was 150 % more for the later year, and the ratio of expenditure to receipts had increased from 63.45 in 1913 to 80.44 in 1922.

That, despite the concessions made to the men — made, be it remembered, by the Government or at its orders, and generally without the concurrence of the companies — and the high price of materials, coal, stores, etc., the companies have run the railways for roughly sixteen shillings out of every pound they received, and have four shillings left wherewith to pay interest on their capital and to put to reserve, is a result on which the country as much as the shareholders may be congratulated. The results become the more remarkable when it is remembered that the road and rolling stock have been brought again to their pre-war high standard. But some may wonder why, in these circumstances, reductions in rates and fares were small. We believe the answer to be that the signs of improving trade were not in the least definite, and are not even yet sufficiently strong to warrant great optimism. Moreover, until its terms for amalgamation or absorption definitely were secured, no company

would do anything that would prejudice its financial standing. Especially was this so with those companies which contended that their position had been improved since 1913, the year on which the negotiations mainly were based. The opposition of these companies to any reduction was, in view of the interrelation of all the companies, sufficient to spoil the good intentions of the others. The drop in passenger fares from roughly one penny three-farthings per mile to three-halfpence may seem small; but, as the passenger receipts in 1921 were seventy millions sterling, that reduction alone means a sacrifice of about eight millions a year. As the net receipts of the seventeen companies were less than two and a-half millions above the 1913 figure, the reductions in rates and fares already made would appear to indicate a highly optimistic spirit, and yet some of the chairmen have expressed hopes of making still further concessions.

In the second table we indicate the increases of 1922 over 1913 in the main items of expenditure of two typical companies — the Midland and the Great Northern — whose ratios of expenditure to receipts were 79 and 80.02 respectively, as compared with the average of 80.44 for the seventeen companies. It will be seen that the Midland had in 1922, as compared with 1913, a percentage increase of 165.99 in maintenance and renewal of way and works, of 143.33 in maintenance and renewal of rolling stock, of 174.25 in locomotive running wages, of 94.66 in fuel, of 130 33 in other running expenses, of 125.12 in traffic salaries and wages, and of 115.18 in other traffic expenses. The higher price of material had some effect upon the first two of these items, but to all of them the direct increase in the cost of labour contributed.

It is the fact that any reduction in railway rates at once favourably affects the price of all commodities and manufactured material. This is a benefit the companies themselves enjoy, as they are large purchasers of materials and stores. Hence, a reduction in the cost of railway labour benefits the companies, and, through them, traders generally. Yet the railway unions reasonably may ask why should their members be made to take the lead in having their wages dropped. We invite them to turn back to 6 December 1918, when Lord Ashfield, the then President of the Board of Trade, met them. He then not only promised the eight hours' day as from 1 February 1919, but agreed that a new committee to deal with pay and conditions should forthwith be set up. Meetings were, as a consequence, held, by which many concessions over and above the eight hours' day were made to the men. These concessions were in the shape of a more liberal payment for overtime and Sunday duty, payment if called out for work and then not required, longer holidays, etc. All this was very generous, but the spirit prevailing at that time must be remembered. The Armistice was signed, hostilities were over and the enemy thoroughly beaten. Large reparations were talked of, and all were grateful to the men for the sacrifices they had made. But more had been promised than could economically be granted, and modifications of the National Agreement then concluded are now under discussion. The reductions are a real necessity. If the moderation hitherto shown by both sides be continued, we may expect the railway labour costs shortly to be further curtailed, with, as we have said, benefit not only to the companies, but, through them, to the traders and to the country as a whole. So much for the reduction of rates; but there remains another question of not less importance to the traders and the railways. We refer to the nature of the business relationship which exists between them. On the London, Midland and Scottish, for instance, there is one general manager, with a deputy general

TABLE I.

Expenditure of seventeen British railways as now grouped in 1922 as compared with 1913.

—	Expenditure in 1922.	Increase in expenditure 1922 over 1913.	Increase or decrease in net receipts, 1922 over 1913.	Ratio of expenditure to receipts. 1913.	1922.
London Midland & Scottish :	£	£	£		
(1) London & North-Western . .	36 517 288	20 390 367	+ 649 596	65.94	79.74
Midland	21 615 447	11 441 410	— 39 313	62.22	79.00
North Staffordshire.	1 776 552	1 057 010	— 130 157	63 64	86.52
Furness	839 280	441 849	— 130 252	58.16	86.36
Caledonian	7 384 736	4 091 613	+ 94 090	59.76	77.40
Glasgow & South-Western. .	3 210 233	1 818 825	— 87 658	61.99	82.13
Highland.	910 191	569 270	— 22 135	57.73	79.87
Total for group. . .	72 253 727	39 810 344	+ 334 171	64.18	79.75
London & North-Eastern :					
(2) North-Eastern	18 144 052	9 741 463	— 612 156	64.39	83.68
Great Central	9 715 618	5 248 174	+ 77 542	67.73	83.41
Great Eastern	10 970 895	6 305 825	— 412 410	68.36	87.13
Great Northern	10 398 127	5 682 519	+ 296 188	67.24	80.02
North British	8 011 516	4 753 225	+ 123 329	57.64	78.65
Great North of Scotland . .	761 482	479 713	— 36 384	54.41	80.29
Total for group. . .	58 001 690	32 210 919	— 563 891	65.51	81.69
(3) Great Western	31 102 976	18 500 168	+ 347 235	64.05	81.29
Southern :					
London & South-Western	9 183 932	5 129 355	+ 171 184	64.17	78.26
South-Eastern & Chatham. .	7 228 431	3 703 076	+ 186 945	62.07	78.07
London, Brighton & South Coast	5 349 242	3 016 250	+ 19 943	61.79	79.17
Total for group	21 761 605	11 848 681	+ 378 072	64.60	78.92
Total for seventeen companies ..	183 119 998	109 925 129	+ 242 972	63.45	80.44

(1) Figures for 1913 include Lancashire and Yorkshire.
(2) Figures for 1913 include Hull and Barnsley.
(3) Figures for 1913 are for Alexandra Dock, Barry, Cambrian, Great Western, Rhymney and Taff Vale.

TABLE II.

Details of the increase in expenditure of two typical companies.

—	Midland. Increase in 1922 over 1913.	Midland. Percentage of increase.	Midland. Percentage of traffic receipts. 1913	Midland. Percentage of traffic receipts. 1922.	Great Northern. Increase in 1922 over 1913.	Great Northern. Percentage of increase.	Great Northern. Percentage of traffic receipts. 1913.	Great Northern. Percentage of traffic receipts. 1922.
Maintenance and renewal :	£				£			
Way and works	2 003 502	165.99	8.62	12.67	874 262	133.47	11.05	13.81
Rolling stock	2 277 501	143.33	11.35	15.26	941 064	142.67	11.15	14.47
Locomotive running :								
Wages	1 536 567	174.25	5.83	8.84	658 075	176.00	5.55	7.94
Fuel	852 026	94.66	5.95	6.40	313 443	63.32	7.35	6.15
Other expenses	184 943	130.33	0.94	0.67	154 538	119.79	1.92	2.15
Traffic :								
Salaries and wages	2 662 545	125.12	14.07	17.51	326 724	137.77	14.28	17.54
Other expenses	1 011 502	115.18	5.80	6.88	411 207	102.75	5.91	6.15
General charges	346 868	115.62	2.14	2.55	144 882	100.61	2.44	2.61
Compensation . . . . Dec.	34 834	...	1.27	0.57	3 004	5.40	0.95	0.54
Rates	368 412	77.40	3.40	3.33	200 778	88.84	3.81	3.86
Other expenditure	989 434	134.69	4.85	6.30	846 674	202.55	6.20	9.69

manager for Scotland; on the London and North-Eastern there is a chief general manager, a general manager for Scotland and two divisional general managers for England; on the Southern the *statu quo* remains as yet, and there are three general managers — each, apparently, independent of the others. On the London, Midland and Scottish, and the London and North-Eastern, the arrangements for the civil engineer's and Mechanical engineer's departments have now been settled. Herein, again, there has been no change with the Southern Railway. The fear that with such large companies touch with traders would be lost is intended to be met on the London and North-Eastern Railway by allowing the divisional general managers a very free hand. Thus, to quote Mr. Whitelaw, the chairman, traders will continue to enjoy their essential rights to have personal contact with a responsible officer in their own area and to discuss with him their difficulties and requirements. On the London, Midland and Scottish there are divisional men of high standing, under the chief general superintendant at Derby and the chief goods manager at Euston respectively. Undoubtedly, in this and other respects the Great Western is in the best position, as practically all the traders on the lines that company has taken over were already acquainted with the Great Western officers and their methods. At the

annual meeting on the 22nd ult., it was said that the old form of departmental organisation had been preserved; the only new feature was the formation of a docks department under Mr. J. H. Vickery, the late general manager of the Alexandra (Newport) Docks and Railway. Whilst, then, it remains to be seen how all the details of amalgamation work out in practice, it is already plain that the companies, recognising the high value of the personal touch which existed between their local representatives and traders, will do their best to preserve it. Il is certain that if that touch is lost, if the man with local knowledge of both persons and affairs is submerged in a soulless organisation, there will be perpetual trouble between the railways and the traders.

From this very brief review of the Railway position and from the two tables to which we have already made reference, it will be seen that the railways have entered upon their first year under the group system in better circumstances than were expected. But the fact remains that rates are still a great deal too high and continual pressure will be necessary to bring about their reduction. Grouping will have achieved nothing at all, it will be no more than the realisation of a costly ideal of organisation, if it does not lead to economies of an order considerably in advance of those which we might fairly have expected under the old competitive system. The companies are now relieved of the cost of competition, and in return for that relief the country expects an improvement in transport facilities and a rapidly diminishing cost of transport. If it does not get these things, no excuses that its protagonists can make will save the grouping system from public condemnation.

MISCELLANEOUS INFORMATION

[625 .143]

1. — An improved type of sole plate for attaching flat bottomed rails to sleepers and a new method of attaching rails to ferro-concrete sleepers.

Figs. 1 to 5, p. 960.

(*Giornale del Genio Civile.*)

Before the war, the question of sleepers for railway lines caused some anxiety; the demand for English oak sleepers was considerably greater than formerly, and resulted in the depletion of the forests from which this wood was obtained. The situation gradually grew worse for the two following reasons: on the one hand, the slowness of growth and the continual rise in price of these sleepers; and on the other hand, the unsatisfactory results obtained with sleepers (ordinary oak, beech, pine) from other sources, although creosoted in the usual way, and this led to the trial of metal sleepers and those of ferro-concrete.

The difficulties which this important problem opened up brought to light all the conditions which are demanded of a sleeper, which must be solid and durable between the various component parts of the track, but must also have sufficient elasticity for a small amount of bending in order to withstand the blows to which it is subjected, so as to help towards the better preservation both of the road itself and of the rolling stock. Furthermore, after a number of years the hammering becomes greater, because of the continual tendency to increase the speed and weight of vehicles running on the railways. It will be seen therefore that the solution of these problems presents great difficulties.

In the meantime, whilst the question of a practical type of ferro-concrete sleeper was under consideration, it was agreed to continue to employ wooden ones containing those qualities which had given the most satisfactory service previously, and to make use of ferro-concrete sleepers which were either in service or being made, but at the same time to observe which type best answered to the demands and which best withstood the influence of mechanical work and of time.

Such is the problem that confronts us, and which experience has shown can be solved. By the courtesy of Mr. Giuseppe Borini, Director of the Reggio Emilia Railways, we are able to give a short description (aided by those articles published by Mr. Borini in numbers 1 and 3 of the *Rivista dei trasporti*, 1922, and to whom we are obliged for forwarding them to us in book form) of the rail sole plates on the sleepers used by that Railway and Mr. Borini's system of fixing the foot of the rails to ferro-concrete sleepers.

A type of wooden sole plate, protected by a metallic frame, was designed by Mr. Borini in 1905 and experimented with good results on the light railways and on some of the State railways, on which more than 400 000 were used. They are also used at the present time on the sections using ferro-concrete sleepers. This sole plate, designed to be placed between the foot of the rail and sleepers made of any material, including ferro-concrete, in place of metal sole plates or those of wood without ironwork, consists, as shewn in figure 1, of two parts: a piece of wood, and a metallic frame which forms the ironwork. The piece of wood is rectangular in plan and has a vertical section in the form of a trapezium usually having a taper of 1 in 20, and with holes for the coach screws; it is generally made of any wood which is found to be hard enough and of greater durability than that generally used for sleepers; the common oak

of the Apennines well fills these conditions, as does American quebracho, which is very hard and has a life of over thirty years. In using this latter timber, it is possible to reduce the thickness of the wood considerably and also the ironwork. The latter is a steel casting and has, on each of its sides which are parallel to the rail, a boss which serves to hold the tightening plate which furnishes a constant contact between the foot of the rail and the wood.

The thickness of the wood, relative to the height of the sides of the ironwork, is such that the latter, never quite comes in contact with the sleeper, so that there is no fear that the ironwork itself will undergo the small deformations to which the wooden tablet is subjected.

The Borini sole plate offers a greater and more flexible support than the ordinary metallic sole plate, and its use eliminates the usual notch in the wooden sleeper and, in ferro-concrete, one does away with the crushing which is invariably produced by contact with the rail. It will be admitted that owing to the nature of the materials used in this system, the contact is more perfect, and surfaces in contact have a greater resistance to the destructive action of the atmosphere, so that the support becomes more stable and remains so. There is also a great advantage in fixing, because the joint is better and correctness of gauge is ensured.

All the advantages which we have shewn were proved in the Borini sole plate of the old type. However, these have not completely fulfilled the intentions of the inventor, because the ironwork made of section iron has not sufficient resistance, and also as it rests unprotected on two ribs, it does not sufficiently protect or reinforce the wooden plate. In addition, the coach screw clips do not allow taking up the play which inevitably develops between the foot of the rail and the coach screws themselves, play prejudicial to the stability and strength of the system.

The new sole plate (fig. 2) is free from all these defects. In fact, the ironwork, strengthen by a reinforcing rib on the four sides, is stronger and protects the wood better. Further, the new Borini sole plate fulfills all the conditions necessary to give to the support and the attachment the maximum of strength and stability. Finally, it preserves better the surfaces in contact from deformation produced by mechanical action and against the variations of the atmosphere.

For improving the conditions of lines laid on ferro-concrete sleepers still more, Mr. Borini has designed, as we have previously stated, a new system of attaching the rails to these sleepers.

This second invention of Mr. Borini consists of a wedge or pad made of wood, having in the middle of its base a cavity designed to receive a metal sleeve in which is a cut screw thread.

The wedge is either sunk into the ferro-concrete sleeper or is cast into it, its exact position being determined by the gauge used for laying the line. The sleeve and the bolt are fitted before the sleepers are placed in position for the rails.

Figure 3 is an elevation of the bolt and the sleeve. Figure 4 shews an elevation and a plan of the wooden wedge, whilst figure 5 is a vertical section of the rail, the sole plate, and the sleeper with attachments.

It will be seen that the wedge A takes the shape of a truncated pyramid; it can also be conical or any other form, provided that the greatest dimension does not exceed 1 9/16 inches at the summit or 2 5/16 inches at the base, this is necessary in order to prevent weakening the sleeper excessively. It has a hole D running through its centre, for the bolt C, and this hole is enlarged at the base to receive the metal sleeve B. It may be of any kind of wood, providing it is sufficiently strong and durable. The same wood as that used for the wooden plate of the sole plate, common Apennine oak, fills both these conditions well, but American quebracho is much better because it ensures the evenness of the wedge and has a durability superior to that of the sleepers, while quebracho sleepers, as has been stated, have a life of over thirty years. The sleeve B is made of iron of square or other section: it is tapped and thus forms a nut which fits the bolt C.

The new method of attachment presents considerable advantage over the coach screw,

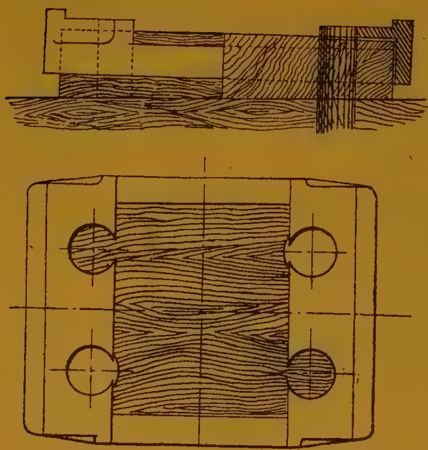


Fig. 1.

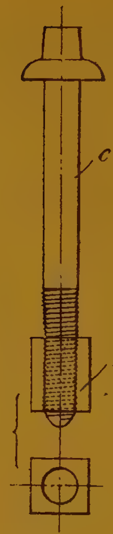


Fig. 3.

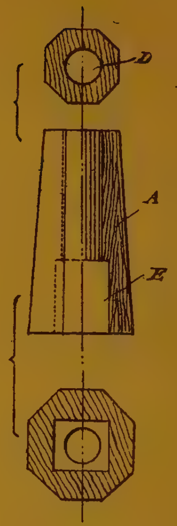


Fig. 4.

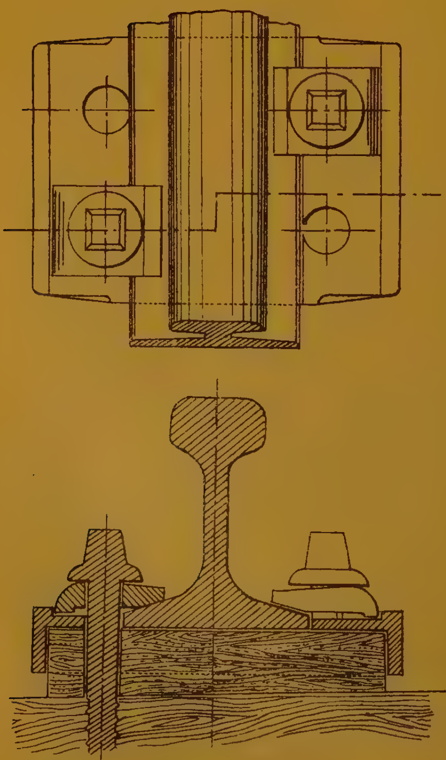


Fig. 2.

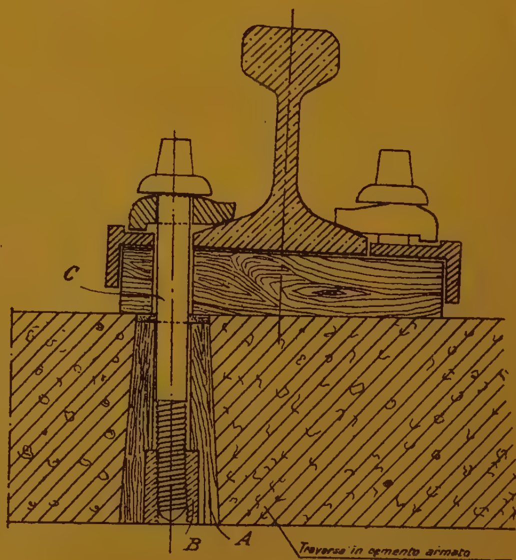


Fig. 5.

Explanation of Italian terms :

Traversa in cemento armato = Reinforced concrete sleeper.

screwed directly into the wooden sleeper or in plugs in ferro-concrete sleepers. These advantages are as follows:

a) The resistance to the pulling out of the fastening is considerably increased; it varies, in fact, with the shearing strength of the lateral surface of the wooden prism along the whole of its length. Experiments carried out with perfectly sound wood have shown that the new attachment will withstand, without shewing the least movement, a pressure of 44 000 lb., whilst with a pressure of 2 200 lb. a fastening with an ordinary coach screw shews signs of lifting.

b) The connection between the bolt and the nut is perfectly protected from the destructive action of the weather, because it is placed inside the body of the sleeper itself. With the ordinary attachment by means of coach screws, after a certain number of years, one finds alterations in the screw at the head of the coach screw, whereas at the lower end the screw remains intact.

c) With the coach screw system, owing to vibrations produced by running trains and transmitted to the coach screw, the screws themselves quickly become loose and tear away the wooden fillets, so that the rigidity and consequently the strength of the connection becomes weakened, and it may break away altogether. The new system remedies this defect, and at the same time guarantees a better and more permanent contact between the various parts of the road.

d) With the new system, vibrations have less effect on the sleepers because they are taken towards the base where the sleepers themselves are strongest and less subjected to stress. Furthermore, the vibrations are for a great part absorbed by the bolt, the sleeve and the wooden wedge, and do not exert any appreciable effect on the sleepers.

This new system of fastening together with the armed sole plate certainly contributes to the speeding up of the solution of the important problem of ferro-concrete sleepers, a solution which is forced upon us in order to prevent the depletion of our forests and owing to oak sleepers day by day becoming more exhorbitant in price.

[**621** .87 (.494)]

2. — Electrically operated 25 t. Goliath crane at the goods station at Zurich,

From W. DRUEY, engineer.

Fig. 1, p. 962.

(*Bulletin technique de la Suisse romande.*)

The crane referred to in the following description is designed for loading and unloading furniture vans. It is also provided with auxiliary crabs for handling all types of goods.

The loading and unloading of vehicles on railway wagons can be done in two ways. In the case of small stations, a ramp placed level with the wagons for loading is sufficient; the men are quite able to deal with the work, providing the weight of the vehicle and shafts does not exceed a certain limit. The other method is to employ a fixed or moving crane, power driven. Until recently the goods station at Zurich was equipped with a hand power crane which required four men to operate it. The constantly increasing traffic at this station caused the Federal Railways to instal modern equipment, and an electrically operated crane was constructed by the Œrlikon Constructional Works. This is shewn in figure 1.

The time necessary to load a furniture van, that is to say, a lift of 4 ft. 11 in., a horizontal movement of 11 ft. 6 in. and lowering the vehicle into the wagon, by means of a hand crane worked by four men is approximately 20 minutes. The same work can be done in 50 seconds with a modern crane.

The chief points of the crane are:

The main crab which can lift (working load) a weight of 55 000 lb.

The auxiliary crabs which can lift (working load) 22 000 lb.

The track of the rails of the Goliath is 50 ft. 10 in. The total length of the girder on which the carriage runs is about 62 ft. 4 in.

The loading gauge of the crane is 49 ft. 3 in. wide by 23 ft. 7 1/2 in. high.

The running rail of the machine is 87 1/2

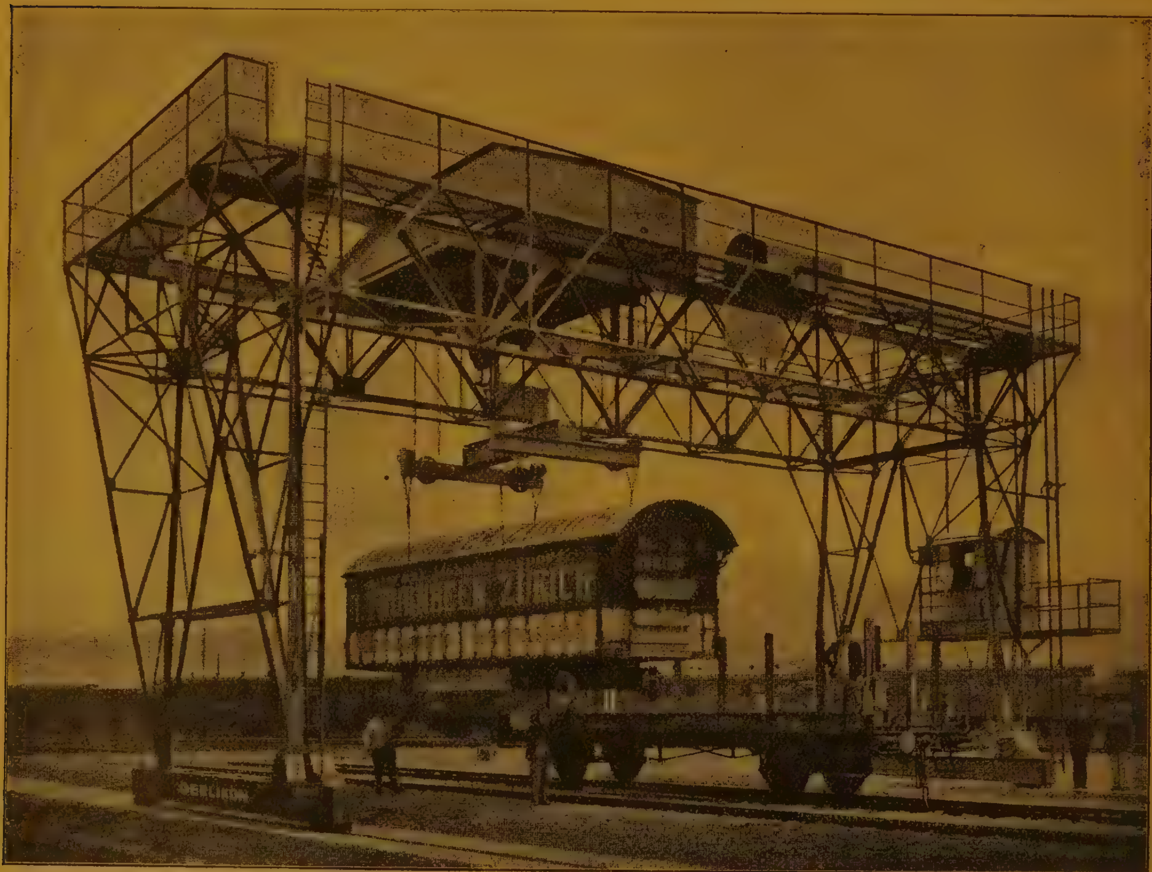


Fig. 1. — 25 t. Goliath crane at Zurich station.

yards long; it has a gradient of 3 ⁰⁰/₀₀ and has spring buffer stops at each end.

The travelling speed, with the maximum load under a wind pressure of 10.24 lb. per square foot, is 164.05 feet per minute with a 26 H. P. motor.

The lifting speed with a working load of 55 000 lb. is 9.19 feet per minute; a 26 H. P. motor is used.

With the auxiliary crabs the lifting speed is 18.04 feet per minute, with a 18 H. P. motor.

The traversing speed of the crabs is 62.02 feet per minute; a 5 H. P. motor is used for this purpose.

The stability of the crane in the greatest winds of the district is assured, these winds are estimated at 30.72 lb. per square foot.

[621 .33 (.75)]

3. — Electrification of the Virginian Railway.

The *Railway Age* of the 5 May 1923 states that the Virginian Railway has decided to electrify a section of its line, 134 miles in length and having 213 miles of track.

The section is at the western end of the line and lies between Roanoke, Va., and Mullens, W. Va., where the railway crosses the Allegheny Mountains. The trains have to be drawn eastward up a gradient of 1.98 % before descending towards the sea.

The greater proportion of the traffic of the line consists of coal. The importance of this traffic has led the Company to adopt special means to deal with it. They use wagons having a capacity of 120 (short) tons which are made up into very heavy trains handled by the most powerful locomotives.

The incline of 1.98 % is 11 miles in length and extends to Clarks Gap, which is the summit. The trains have a tonnage of 5 500 tons and are drawn up the gradient at a speed of 7 miles per hour by three *Mallet* locomotives, which develop in all 7 000 H. P.

At the summit two of the locomotives are detached and the remaining locomotive at the head of the train takes it down the falling gradient. This latter includes an incline of 1.5 % 12 miles in length and necessitates careful braking, and it has been largely as a consequence of this situation that the Virginian Railway has been something of a leader in the use of the empty and load brake.

The object of the electrification is to increase the loading and the speed of the trains. It is proposed, by the use of locomotives developing 20 000 H. P. per train, to haul 9 000 ton trains up the above mentioned gradient at a speed of 14 miles per hour. The Westinghouse Electric & Manufacturing Company, who have secured the contract for the electrification, has stated that it will be entirely practical to further increase this power so that 12 000 ton trains may be handled at the same speed.

The system chosen for transmission is monophase. Power will be generated by a 90 000 H. P. generating plant and transmitted at 88 000 volts by a line approximately following the railway to sub-stations, where it will be stepped down to 11 000 volts for the trolley wire. This voltage will be still further reduced and converted to three-phase on the locomotives. This system will allow of the use of regeneration braking on down grades, and this will assist in the control of the trains, and it is estimated will save 15 000 000 kilowatt hours per annum.

The work will entail an expense of $15 000 000, and is the largest railroad electrification contract ever placed and it is expected that electric operation will be started in about eigtheen months.

[621 .335]

4. — New type of transmission by coupling rods for electric locomotives.

Figs. 1 to 2. p. 964.

The *Revue générale des chemins de fer*, in its number for February last, published under the signature of Mr. Joseph Bianchi, chief mechanical engineer of the Italian State Railways the following description of a new type of transmission by coupling rods for electric locomotives :

« There has recently been applied to a high speed three-phase locomotive of the Italian State Railways, a new system of articulated coupling rods, which offer numerous advantages over other systems of transmission by triangular coupling rods which have so far been employed.

« This system, as applied to locomotive E 330-14, is shown diagrammatically in figure 1.

« A rod MN couples the crank pins of the two motors together. Two oblique rods of equal length 1-3 and 2-4 are joined at 1 and 2 to the rod MN, and at their other ends 3 and 4 to the levers Z and W, which can turn round points 7 and 8 on the centre of the rod AB coupling two of the wheels.

« A short rod 5-6 couples the levers Z and W and causes them to be displaced through equal angles, but in opposite directions.

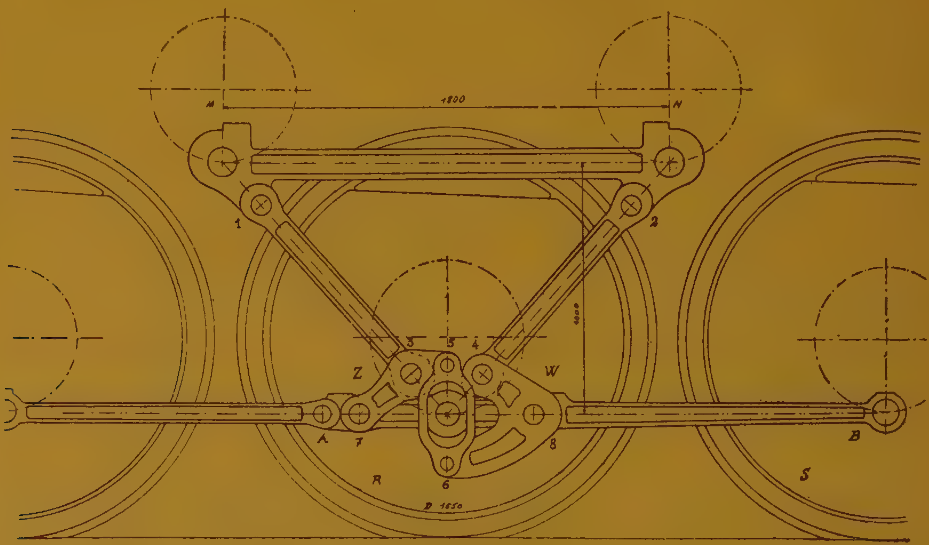


Fig. 1.

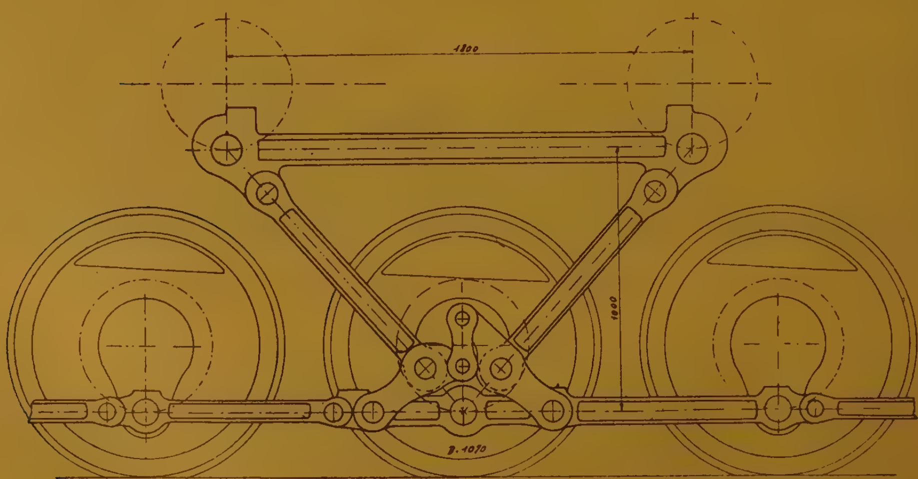


Fig. 2.

« The length of the lever arms 7-3 and 8-4 are equal, as are the lever arms 7-5 and 8-6.

« The axes of the rods 1-3 and 2-4 are compelled to form the sides of an isosceles triangle,

the base of which is the axis of the rod MN and the apex O which is always on the axis of the coupling rod AB.

« In the mean position the axis of the small rod AB also passes through the apex of the isosceles triangle.

« It is easy to see that only the vertical components of the effort on the crank pins of the motors is not transmitted to the wheels, whilst the horizontal components are transmitted entirely.

« In effect, all vertical displacement relative to the rod MN transmitted to the rod AB is only transmitted by the rods 1-3 and 2-4 turning about the points 1 and 2 and by the levers Z and W turning about their axes 7 and 8 through equal but opposite angles. Now this movement is produced by the little rod 5-6 and therefore will be produced without the rod AB being affected by any vertical movement of the frame of the vehicle.

« On the other hand, any horizontal movement relative to the rod MN will not be transmitted to the rod AB because it will only tend to move the levers Z and W in the same direction, and this is impossible because of the short rod 5-6.

« The system therefore cannot be distorted, and the movement of MN and AB are identical.

« The length of the levers and the position of their axes should be calculated so that the resultant of the forces transmitted to the rod coupling the wheels is horizontal and passes through the rod in all positions of the frame and wheels which they assume owing to the oscillation of the springs.

« This is absolutely necessary so that the rod AB is not subject to bending stresses.

« This system of articulated rods may be applied in other forms. Figure 2 gives an example of its application to wheels of small diameter. In this case it allows of the cranks being of the greatest possible throw. »

The first part of the article dealing with the description of the new type of transmission is reproduced here above.

The readers of the *Bulletin* who desire further particulars may usefully look through the article as a whole. It deals with the advantages which have accrued through the adoption of this new method of transmission from the point of view of it allowing the motors to be raised, the weight of the transmission gear being lightened and also the possibilities of balancing the rotating parts.

Other very interesting matter is included in the article, which refers to the calculations of the rods and laying them out.

385. (06.111]

OFFICIAL INFORMATION

ISSUED BY THE

PERMANENT COMMISSION

OF THE

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

Meeting of the Permanent Commission on the 28 July 1923.

The Permanent Commission of the International Railway Congress Association met on the 28 July 1923 at the Head Office of the State Railways, Brussels, with Mr. Tondelier, president, in the chair.

* * *

I. — In virtue of the powers conferred by the General Meeting on the 27 April 1922 of the Rome Congress, the Permanent Commission nominated Mr. R. B. D. Blakeney, director general of the Egyptian State Railways, Telegraphs and Telephones, and Mr. J. Aoki, inspector general of the Japanese Ministry of Railways, to represent these two countries on the Permanent Commission.

* * *

II. — The auditors appointed by the Rome Congress to verify the accounts for the period 15 April 1911 to the 31 December 1922 presented their report. They state that the accounts have been very accurately kept.

The balance sheet for the social year 1922 has been submitted the 5 June 1923 for examination to all the members of the Permanent Commission.

This account has been checked by a professional accountant and was approved of, as was also the projected budget for the social year 1923.

The variable annual subscription of the adherent administrations (article 17 of the statutes) was fixed at 35 centimes per kilometre for the current year 1923.

* * *

III. — All the reporters on the questions on the programme for the next Congress, which will be held in London in the course of the second half of the year 1925, have already been nominated (see attached).

The detailed questionnaires dealing with a large number of these have already been sent out to the administrations belonging to the Association; the answers should come in by the end of the present year.

* * *

IV. — The Local Organising Committee

of the London Congress is at present composed as follows :

The Right Hon. Sir Evelyn CECIL, G. B. E., M. P., privy councillor, director, Southern Railway (member of the Permanent Commission of the Association);

Messrs. G. BEHRENS, director, London Midland & Scottish Railway (member of the Permanent Commission of the Association);

F. J. C. POLE, general manager, Great Western Railway Company;

Arthur WATSON, first general manager, London Midland & Scottish Railway (member of the Permanent Commission of the Association);

R. L. WEDGWOOD, general manager, London & North Eastern Railway;

Sir Herbert WALKER, general manager, Southern Railway (South Western Section);

Sir Henry FOWLER, deputy chief mechanical engineer, London Midland & Scottish Railway;

Messrs. Roger SMITH, electrical engineer, Great Western Railway;

F. A. BRANT, Southern Railway (South Eastern Continental Committee);

Secretary : Mr. Arthur B. CANE, secretary of the Railway Companies' Association.

Messrs. POLE, WEDGWOOD, Sir Herbert WALKER, Sir Henry FOWLER, Messrs. SMITH, BRANT and CANE have been, in accordance with article 6 of the statutes, made temporary members of the Permanent Commission.

Other Englishmen will be appointed shortly to join this Local Committee.

* * *

V. — The following alterations have taken place since the last meeting :

ADMINISTRATIONS.

Admissions.

	Kilom.	(Miles.)
Société des transports en commun de la région parisienne	1 010	(628)
Underground Electric Railways Company	101	(63)
Chemins de fer Pirée-Athènes-Péloponèse	750	(466)
Chemins de fer d'État de la colonie de l'Afrique occidentale française	2 304	(1 432)
Chemins de fer de la colonie de l'Indochine	1 216	(756)
Canadian National Railways	28 765	(17 874)

Resignations.

Central Vermont Railway	863	(536)
Chemins de fer de Grande-Banlieue	240	(149)
Chemins de fer des Côtes-du-Nord	219	(136)
St. Louis South Western Railway	2 538	(1 577)
Chemins de fer d'intérêt local de l'Yonne	142	(88)
Compagnie Meusienne de chemins de fer	168	(104)
Chemins de fer du Beaujolais	91	(57)
Baltimore & Ohio Railroad	7 170	(4 455)
Chicago, Peoria & St. Louis Railway	378	(235)

On account of the amalgamation of the principal English Companies into four groups, and of that of certain Companies in other countries, the Association consists at the present day (July 1923) of 228 administrations whose lines comprise 431 300 kilometres (268 000 miles).

QUESTIONS

FOR DISCUSSION AT THE LONDON SESSION (1925)

WITH

THE NAMES OF THE REPORTERS

1st SECTION : WAY AND WORKS.

I. — Maintenance of the track. Level crossings (public roads).

A) Different methods of maintenance and repair of the track. (By the administration, by contractors, by piece work or premium system. Mechanical appliances, etc.). Comparison from the technical and economical points of view;

B) Dispensing with crossing keepers. Visibility of the trains from the crossing : warning notices and signals, etc.

Reporters :

Great Britain and colonies. — Mr. Coomber (W. H.), divisional engineer (permanent way), London Midland & Scottish Railway; Hunt's Bank, Manchester.

America. — A and B. — Mr. Ray (G. J.), chief engineer, Delaware, Lackawanna & Western Railroad; Hoboken, N. J.

France. — A and B. — Mr. Ruffieux, ingénieur en chef au service central de la voie de la Compagnie des chemins de fer de Paris à Lyon et à la Méditerranée; 3, rue de Lyon, Paris (XIIe).

Italy, Spain and Portugal. — B. — Mr. Mendizabal (Domingo), ingénieur en chef de la division du matériel fixe de la Compagnie du chemin de fer de Madrid à Saragosse et à Alicante; 2, Pacifico, Madrid.

Other countries. — A. — Mr. Deyl (H.), ingénieur, conseiller ministériel au Ministère des Chemins de fer de l'Etat tchéco-slovaque; Prague. — *B.* — Mr. Maas Geesteranus, ingénieur en chef des voies et travaux des Chemins de fer néerlandais; Utrecht.

II. — Breaking of rails. Joints.

A) Initial causes of breaking of rails : means employed to reduce the number of these breakages, as much from the point of view of the method of use as from that of the specification of material employed;

B) Rail joints : most economical and efficient arrangement.

Reporters :

Great Britain and colonies. — Mr. Brown (C. J.), chief engineer, London & North Eastern Railway (Great Northern and Great Central sections); King's Cross Station, London, N. 1.

America. — Mr. Cushing (W. C.), engineer of standards, Pennsylvania Railroad System; Broad Street Station, Philadelphia, Pa.

France. — Mr. Merklen, ingénieur en chef de la voie et des bâtiments des Chemins de fer d'Alsace et de Lorraine, 3, boulevard du Président Wilson, Strasbourg, and Mr. Cambournac, ingénieur en chef des études, matériel des voies et bâtiments de la Compagnie du chemin de fer du Nord français, 18, rue de Dunkerque, Paris (X^e).

Other countries. — Mr. Willem, ingénieur en chef, directeur d'administration, président de la Commission de réception du matériel de la voie des Chemins de fer de l'Etat belge; 76, rue Belliard, Brussels.

III (1st and 3rd sections jointly). — **Shunting yards.**

Shunting and marshalling yards for goods trains. Lay-out and organisation.

Reporters :

Great Britain and colonies. — Mr. Nicholls (R. H.), superintendent of the Line, Great Western Railway; Paddington Station, London, W. 2.

America. — Mr. Wagner (Samuel T.), chief engineer, Philadelphia & Reading Railway; Reading Terminal, Philadelphia, Pa.

France and Belgium. — Mr. Moutier, sous-chef de l'exploitation de la Compagnie du chemin de fer du Nord français, 18, rue de Dunkerque, Paris (X^e), and Mr. Pellarin, ingénieur en chef adjoint de la voie et des travaux de la Compagnie des chemins de fer de l'Est français, 23, rue d'Alsace, Paris (X^e).

Other countries. — Mr. Simon-Thomas (W.), ingénieur, chef de division au service de l'Exploitation des Chemins de fer néerlandais; 9, Frederik Hendrikstraat, Utrecht.

2nd SECTION : LOCOMOTIVES AND ROLLING STOCK.

IV. — **Reduction of the cost of traction.**

A) Fuel and its combustion :

a) Choice of fuel : coal, mixing of coals, peat, oil fuel, pulverised fuel, mixing of solid and liquid fuels (colloidal fuel);

b) Apparatus for the combustion of solid fuel (rocking-grates, etc.), liquid and pulverised fuels;

c) Mechanical stokers;

d) Smoke consumption. Spark arresters.

B) Lubrication of axleboxes for all rolling stock :

a) Axleboxes. Plain bearings. Roller and ball bearings;

b) Lubricants.

Reporters :

America. — *A and B.* — Mr. EMERSON (Geo. H.), chief of motive power, Baltimore & Ohio Railroad; Baltimore, Md.

Great Britain and colonies. — *A.* — Mr. COLLETT (C. B.), chief mechanical engineer, Great Western Railway; Swindon, Wilts. — *B.* — Sir HENRY FOWLER, deputy chief mechanical engineer, London Midland & Scottish Railway; Derby.

Other countries. — *A.* — Mr. CHENU, ingénieur en chef, inspecteur de direction aux Chemins de fer de l'Etat belge; 21, rue de Louvain, Brussels. — *B.* — Mr. TETE, ingénieur principal de la 2e division du matériel de la Compagnie des chemins de fer de Paris à Lyon et à la Méditerranée; 20, boulevard Diderot, Paris (XIIe).

V. — Electric locomotives.

High speed electric locomotives.

Reporters :

America. — Mr. WALLIS (J. T.), chief of motive power, Pennsylvania Railroad System; Broad Street Station, Philadelphia, Pa.

Other countries. — Mr. WEISS (M.), ingénieur en chef de la traction à la Direction générale des Chemins de fer fédéraux suisses; Berne.

VI (1st AND 2nd SECTIONS JOINTLY). — Locomotive sheds.

Arrangement of locomotive sheds.

Installations :

a) for inspecting engines;

b) for washing out boilers and blowing through the tubes;

c) for lighting up of engines and getting rid of the smoke;

d) for loading fuel on the engines. Mixing fuels. Disposal of ashes;

e) for the recovery of coal and coke from the residues of combustion.

Reporters :

America. — Mr. BELL (R. W.), general superintendent motive power, Illinois Central Railroad; Chicago, Ill.

Great Britain and colonies. — Mr. MAUNSELL (R. E. L.), chief mechanical engineer, Southern Railway (South Eastern & Chatham section); Ashford (Kent).

Other countries. — Mr. JACOMETTI (Jacometto), ingénieur en chef du service du matériel et de la traction des Chemins de fer de l'Etat italien; Florence.

3rd SECTION : WORKING.

VII. — Dispatching or control systems.

Reporters :

America. — Mr. HUTCHENS (H. E.), general inspector of passenger transportation, Southern Railway System; Washington, D. C.

Great Britain and colonies. — Mr. FOLLOWS (J. H.), chief general superintendent, London Midland & Scottish Railway; Derby.

Other countries. — Mr. EPINAY (E.), ingénieur en chef adjoint au chef de l'exploitation de la Compagnie du chemin de fer de Paris à Orléans; 1, place Valhubert, Paris (XIIIe).

VIII. — Suburban services.

General organisation of suburban services, including tubes, on lines exclusively used as such, or those not used for this purpose only (lay-out of stations and lines, signalling, rolling stock, time-tables, etc.).

Reporters :

America, Great Britain and colonies. — Mr. BLAIN (H. E.), assistant managing director, and Mr. COOPER (A. R.), chief engineer, Metropolitan District Railway and other London Underground Railways; Electric Railway House, Broadway, Westminster, London, S. W. 1.

Other countries. — Mr. DIREZ, sous-chef de l'exploitation des Chemins de fer de l'Etat français; 13, rue d'Amsterdam, Paris (VIIIe).

IX (2nd AND 3rd SECTIONS JOINTLY). — Fixed signals.

Fixed signals. Principles of signalling for lines with dense traffic and for large stations. Form of day and night signals. Signal lights. Automatic block signals.

Reporters :

America. — Mr. ELLIOTT (W. H.), signal engineer, New York Central Railroad; Albany, N. Y.

Great Britain and colonies. — Mr. THORROWGOOD (W. J.), signal and telegraph superintendent, Southern Railway (South Western section); Wimbledon Station, London, S. W. 19.

Italy, Belgium and Holland. — Mr. DE BENEDETTI (Carlo), ingénieur en chef du service spécial des Chemins de fer de l'Etat italien; station centrale, Milan.

Denmark, Norway and Sweden. — Mr. HÅRD (T.), ingénieur principal de l'Administration royale des chemins de fer suédois; Stockholm.

Other countries. — Mr. PINUS, sous-chef de l'exploitation, and Mr. LAIGLE, ingénieur en chef au service central de la voie de la Compagnie des chemins de fer du Midi français; 54, boulevard Haussmann, Paris (IXe).

4th SECTION : GENERAL.

X. — The eight-hour day.

The eight-hour day on the railways.

Reporters :

America, Great Britain and colonies. — Mr. Clower (W.), assistant to general manager (staff and labour), London Midland & Scottish Railway; Euston Station, London, N. W. 1.

Switzerland, Italy, Spain and Portugal. — Mr. Velani (Luigi), chef du service du personnel et des affaires générales des Chemins de fer de l'Etat italien (Direction générale); Rome.

Other countries. — Mr. de Ruffi de Pontevès, ingénieur en chef des mines, directeur du contrôle du travail des agents au Ministère des travaux publics de France; 246, boulevard Saint-Germain, Paris (VIIe).

XI. — Statistics.

Development of railway statistics with the special view of economy in operation.

Reporters :

America. — Colonel Loree (J. T.), vice-president, Delaware & Hudson Company; Albany, N. Y.

Other countries. — Mr. Kirkus (A. E.), director of statistics, Ministry of Transport (Great Britain); 7, Whitehall Gardens, London, S. W. 1.

XII (3rd and 4th sections jointly). — Joint stations and lines.

Allocating the cost of joint stations and lines between several railway administrations.

Reporters :

America, Great Britain and colonies. — Mr. Cope (R.), chief accountant, Great Western Railway; Paddington Station, London, W. 2.

France. — Mr. Collot, ingénieur en chef adjoint de l'exploitation de la Compagnie des chemins de fer de l'Est français, 13, rue d'Alsace, Paris (Xe), and Mr. Bruneau, ingénieur en chef du service central de l'exploitation de la Compagnie des chemins de fer du Midi français, 54, boulevard Haussmann, Paris (IXe).

China and Japon. — Mr. Nakagawa, directeur des services commerciaux des Chemins de fer de l'Etat japonais; Tokyo.

Other countries. — Mr. Lamalle (U.), ingénieur en chef, directeur d'administration aux Chemins de fer de l'Etat belge; 21, rue de Louvain, Brussels.

5th SECTION : LIGHT RAILWAYS AND COLONIAL RAILWAYS.

XIII. — Establishment of light railways.

Methods of establishing light railways or lines for developing new countries. (Laying out, gradients, standard gauge, narrow gauge, etc.)

Reporters :

America, Great Britain and colonies. — Mr. MARRIOTT (H.), assistant to general manager, London Midland & Scottish Railway; Euston Station, London, N. W. 1.

China and Japan. — Mr. TSANG OU, directeur général adjoint de l'Administration du chemin de fer de Lung-Hai, member of the Congress Permanent Commission; 5, rue de Mogador, Paris.

Other countries. — Mr. BONNEAU, ingénieur en chef des ponts et chaussées, ancien inspecteur général des travaux publics de l'Indochine; 6, rue du Boccador, Paris (VIIIe).

XIV. — Concessions for light railways.

Relations between the concessionnaires of light railways and the authorities granting the concession. Economic and financial administration.

Reporters :

All countries. — Mr. BIRAGHI (Pietro), ingénieur, administrateur délégué du chemin de fer de Corleone-San Carlo, Piazza SS. Apostoli, 49, Rome, and Dr. LO BALBO (Pietro), directeur de la Compagnie des tramways à vapeur piémontais, Saluzzo.

XV. — Traction for light railways.

A) Special systems of traction for light railways.

B) Rail motor traction.

Reporters :

America, Great Britain and colonies. — Lieut.-Colonel MANCE (H. O.), C. B., C. M. G., D. S. O., R. E., late director of railways, Light Railways & Roads, War Office; Little Woodbury, Lingfield (Surrey).

Other countries. — Mr. DE CROËS, ingénieur en chef, directeur du service de la traction et du matériel de la Société nationale belge des chemins de fer vicinaux; 48, rue Montoyer, Brussels.

NEW BOOKS AND PUBLICATIONS

[621 .395. (02 & 385. (04]

WHITE (H. G.), A.M.I.E.E. — **Telephone erection and maintenance**, 3rd edition. — One volume 8vo (7 1/2 × 5 inches) of VII + 140 pages with numerous illustrations and diagrams in the text. — Published by S. Rentell & Co., Ltd., 36, Maiden Lane, Strand, London, W. C. 2. — Price : 3 sh. 6 d. net.

This book deals solely with private and domestic telephone systems and does not include any information on public telephone installations.

Chapter I is devoted to small telephones intended to supplement electric house bells.

Chapter II describes various types of battery ringing telephones, while chapter III deals with magneto call telephones for use over longer distances.

Chapter IV deals with intercommunication telephones, that is to say, systems in which every telephone on the installation is able to ring and speak to every other telephone without any operator being necessary.

In Chapter V, secret intercommunication telephones designed to avoid overhearing are described.

Chapter VI deals with switchboard systems in cases where an operator is employed.

The whole of the foregoing chapters are illustrated with wiring diagrams of the various circuits and apparatus used.

Chapter VII is devoted to instrument erection and line construction. Useful information is given as regards the most suitable location of instruments, provision of lightning arresters, establishment of earth connection, erecting pole lines, and overhead and underground cables. Detailed instructions are given as to the best method of carrying out this work. This chapter would appear to be intended chiefly for the assistance of those who have little experience in this class of work.

Chapter VIII is perhaps the most useful in the whole book, dealing as it does with the detection and localising of faults. Various possible forms of failure are quoted and the probable cause of trouble stated.

This little book is written in a straight forward and simple manner, and should be very useful to wiremen and others concerned in the erection and maintenance of private telephone systems.

D. W. S.

[621 .138.5 (02 & 385. (04.]

AHRONS (E. L.), M. I. Mech. E. and M. I. Loco. E. — **Repairing of locomotives.** — Three books 8 inches by 5 1/2 inches of 51, 148 and 281 pages, with two plates and numerous illustrations in the text. — 1920, 1921 and 1922, London, The Locomotive Publishing Co., Ltd., 3, Amen Corner, E. C. 4. — Price : 2 sh. 6 d. each.

These books deal with a subject on which there is very little technical information published. Although the author does not wholly neglect work which

has of necessity to be carried out in the main shops of the railway, he devotes a considerable proportion of his space to the repairs which are carried out at the sheds and local shops attached to them.

The first volume in the first chapter deals with the taking down of various parts of the engine and the examination of the boiler. The first chapter gives a table showing the regulations on the « Midland Railway » as to the time or mileage between the examination of the various parts of the mechanism. A section is also devoted to the various lifting appliances provided at the sheds.

Chapter II (volume I) deals with the operation of dismantling various parts of the locomotive, but the author is dealing with a practice which is uncommon in England when he, on page 24, speaks of boilers being removed « by means of sheer legs in the running shed ». Chapter III (volume I) is devoted to the withdrawal of the tubes, the removal of scale and the examination of the boiler for various defects. On page 32 the author refers to copper and brass tubes, but it may be said that brass tubes are practically never used in locomotives in England, and the practice of cleaning copper ones by immersion in hydrochloric acid is rare. Even in India brass tubes are now rarely used.

The second volume (chapter IV) deals with boiler repairs. The author deals with the various processes carried out in repairing the different parts of the boiler. These include the patching of the firebox, the repair of the tube plates, the dismantling and replacement of roof bars and the fixing of the smoke tubes.

Chapter V (volume III) describes the various small tools which have become indispensable in a modern boiler shop, and these include pneumatic hammers and holders up, pneumatic and electric drills, tube expanders and cutters, apparatus for welding tubes, etc. In chapter VI the reader will find considerable interesting and useful information with regard to various boiler fittings. There are also notes on the smokebox, the joints of the steam pipe and superheater elements, the adjustment of the blast pipe, the adjustment and fixing of the safety valves, the fixing and testing of the pressure gauges and the water gauge frames. The question of the steam pipe joints is gone into very fully.

This concise and necessarily incomplete summary that we have given of « Repairing of Locomotives » will show, however, we trust that the author has produced a useful and eminently practical work. It is illustrated with figures which make it easy to follow the explanations given. We think that it will be read with great interest and benefit, even by those who are familiar with locomotive shop practice.

E. M.

[625 .142.1 (02 & 385. (04]

BEATON (A. J.) major, M. Inst. C. E., M. Inst. T., C. M. G., V. D., F. S. A. (Scotland), late assistant engineer-in-chief, South African Railways & Harbours. — **The problem of the railway sleeper.** — Pamphlet (8 1/2 × 5 1/2 inches) of 34 pages with a few tables, photographs and sketches in the text. Reprinted from the *Transactions of the Minutes of Proceedings of the South African Society of Civil Engineers.* — 1922.

The author deals with the whole situation as regards railway sleepers with special reference to the possibility of a timber shortage in the future and the corresponding need for designing a satisfactory substitute for wood, which at the present is still the predominant material. He discusses steel, reinforced concrete and composite sleepers, and gives particulars of the various steel sleepers in use in South Africa.

As regards wooden sleepers, the author

is of opinion that the present dimensions may in some cases be reduced, and gives a table showing his suggestions. Their life may be prolonged, not only by chemical treatment before use and by good ballast, but also by the use of sole plates which increases the bearing area.

The relative advantages of spikes and coach screws are mentioned; and the opinion is stated that hard wood sleepers are in most cases rendered useless by the action of the spikes before natural decay sets in.

The question is discussed as to whether it is more economical to adopt a system of casual renewal or of sectional renewals of sleepers.

As regards the number of sleepers per mile, tables are given showing the types of permanent way recommended for the 3 ft. 6 in. and 2 foot gauges in use in South Africa, also a diagram showing the relation of the number of sleepers per mile to the axle load in tons.

The paper is followed by a discussion on the points raised and also by communications on the same subject.

D. W. S.

[621 .13 (02 & 385. (04]

GRIMSHAW (Robert), M. E. — **Locomotive Catechism**, 30th edition. — One volume 8vo (7 1/2 × 5 inches) of XI + 958 pages with 468 engravings. — 1923, The Norman W. Henley Publishing Co., 2 West 45th Street, New York. — Price : 4 dollars.

This book is one of those primarily intended to give information by means of questions and answers, of which there are over 4 000 extending over eighty-nine chapters. This method is still in favour in the United States of America as a means of imparting information to practical railroad men and has many advantages, particularly when, as in the case of the book under consideration, matters are explained in a concise and simple manner.

After dealing with the general classification of American locomotives, about forty chapters, covering a quarter of the book, are devoted to the boiler and its accessories. These are followed by chapters on various parts of the mechanism. This portion of the book could be somewhat re-arranged with advantage for — to take one case — valve gears and valve settings are separated by a considerable space from the chapters on Steam Distribution, Slide Valves and Valve Diagrams. Sections are devoted to Steam Consumption, Fuels and Firing and to Compound Locomotives. By far the largest chapter in the whole book, occupying over one sixth of the whole, is devoted to accidents and how to deal with them, and this should be particularly useful to the train staff on lines where the distance is great between stations from which relief can be obtained.

In the present edition, special attention has been given to the unaflow locomotive; the latest design of power brake; the improved superheater and the electric locomotive.

As stated above, the book undoubtedly fills a useful purpose, but it is regretted that it has not been brought more up to date. To give crude illustrations of 4-4-0 and 2-4-2 locomotives each with « cowcatchers » is hardly what one thinks of nowadays as types of « Express Passenger Engines ». To mention one or two examples in the text itself, brass tubes are not now used on English locomotives, and Webb Compounds, of which an illustration is given, are no longer running.

H. F.

[621 .13 (02 & 385. (04]

Locomotive engineers' pocket book and diary, 1923. — A small volume 8vo (3×5 inches) of 300 pages, with numerous illustrations in the text. — 1923, The Locomotive Publishing Company, Limited, 3, Amen Corner, Paternoster Row, London, E. C. 4.

The engineer who designs a locomotive requires to refer to a large number of previous experiments and numerical examples, and it is useful if these can be found brought together in a small book. This is the object of the author of the work we are dealing with.

The question of train resistance is dealt with first of all, and formulæ for the various items which make this up are given with the necessary figures and coefficients, whilst numerous examples are worked out.

Following this, the principal dimensions of the locomotives are touched upon and notes given on fuel and its combustion including figures of the composition and calorific value of the fuels used. The working of the boiler itself is examined in the light of the best recent experience available, and the utilisation of the steam in the cylinders also dealt with. The question of the load on the axles is considered, and its calculation shown both mathematically and graphically. This chapter closes with notes on the tranverse stability on curves and the geometric setting out of the curves.

Various points are dealt with bearing on the design proper, such as, the balancing of the wheels, the form and construction of the boiler, including the calculation of the strength of the rivetted joints, the tyres, the safety valves, the motion, the size of the axles and the material to be employed for the various parts. A number of tables are given to assist calculations.

A very interesting section is devoted to special types of locomotives, including turbine locomotives, those driven by internal combustion engines and those in which a steam engine drives an electric generator, electric motors being used to drive the axle. Other sections deal with the shops, lubrication and such details as injectors, boiler mountings, etc.

Types and dimensions of a number of English locomotives add to the value of the work. The dimensions are given in English notation, but tables allow these to be transfered to the metric system.

From the above it will be seen that this book is one of real value to a drawing office dealing with locomotive construction.

E. M.

[621 .134.5 (02 & 385. (04]

AHRONS (E. L.), M. I. Mech. E. — **Lubrication of locomotives.** — One volume 8vo ($5\ 1/2 \times 8\ 1/4$ inches) of 192 pages with 109 illustrations. — The Locomotive Publishing Company, Limited, 3, Amen Corner, E. C. 4, London. — Price, in cloth : 5 sh. net.

Everyone appreciates the importance of lubrication in the operation of a railway, and especially the lubrication of locomotives. It is one of the essential features on which the regularity of service depends. It also has a considerable influence on the economy of operation by the effect it has on the wear of parts and on the loss of power owing to friction.

This book treats the question in various ways that are of interest to a railway

engineer. Briefly it may be said that it deals with the lubricants, the apparatus and methods employed in using them.

The author does not deal specially with either chemical composition or methods of analysis. These are the physical properties of lubricants, and he devotes his attention more especially to their mechanical properties. He deals with the apparatus which allows these properties to be determined and measured, and chapter I is devoted to this section of the subject.

Chapter II is devoted to the laws of friction and the experiments of Beauchamp Tower relating to the variation of pressure on the surface of bearings.

In the chapters following are described the methods employed for ensuring that the lubricant is supplied to all the wearing parts as well as a number of types of mechanical lubricators. They deal also with axle boxes and their bearings, worsted syphon trimmings and needle lubricators, the lubrication of rods, eccentrics, crossheads, piston rod and valve spindle packings, cylinders and slide and piston valves (displacement and mechanical lubricators) and the brake apparatus. Lubrication of the flanges of tyres is also touched upon.

We would call special attention to the notes on axle boxes and their lubrication by mechanical lubricators, lubrication under pressure and the use of graphite. The employment of the latter was the subject of experiments carried out by professor W. F. M. Goss at Purdue University. Very interesting information is also given on the addition of graphite to the cylinder oil, on the respective merits of displacement and mechanical lubricators, on the question of deposits in the ports and cylinders, on the lubrication of locomotives using superheated steam, and on the use of piston or flat valves for such engines.

The reader will appreciate the tables given at the end of the book recording the oil consumption on several English railways.

E. M.